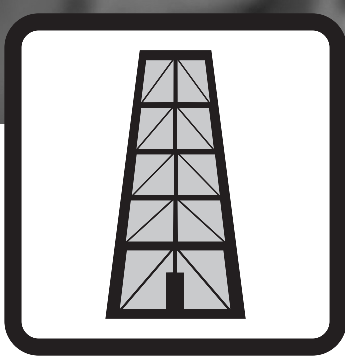
2019-2020

Exploring Oil and Natural Gas

Hands-on explorations, critical thinking activities, and non-fiction text that introduce students to the basic concepts of oil and natural gas formation, composition, exploration, production, and use.



Grade Levels:

- Int Intermediate
- Sec Secondary

Subject Areas:

- Science
- Social Studies
- Math
- Language Arts
- Technology

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National Energy Education Development Project

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The mission of The NEED Project is to promote an energy conscious and educated society by creating effective networks of students, educators, business, government and community leaders to design and deliver objective, multi-sided energy education programs.

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Teacher Advisory Board

In support of NEED, the national Teacher Advisory Board (TAB) is dedicated to developing and promoting standards-based energy curriculum and training.

Energy Data Used in NEED Materials

NEED believes in providing teachers and students with the most recently reported, available, and accurate energy data. Most statistics and data contained within this guide are derived from the U.S. Energy Information Administration. Data is compiled and updated annually where available. Where annual updates are not available, the most current, complete data year available at the time of updates is accessed and printed in NEED materials. To further research energy data, visit the EIA website at www.eia.gov.

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National Energy Education Development

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Exploring Oil and Natural Gas

Peak Oil Game was developed by John Welch, Cabrillo College, and adapted by NEED.

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- 5 Small foam cups
- 5 Large foam cups
- 5 9 oz Clear plastic cups
- 20 Small opaque bathroom sized cups
- 150 Clear straws
- 25 Flexible straws
- 15 600 mL Plastic beakers
- 5 100 mL Graduated cylinder
- 1 Small bottle of food coloring
- 5 Small buttons
- 5 Small corks
- 5 Wooden beads
- 5 Glass marbles
- 5 Pennies
- 10 Kitchen sponges
- 1 Turkey injector
- 2 Bags small rocks (at least enough for 350 mL per beaker)
- 2 Bags medium rocks (at least enough for 350 mL per beaker)
- 2 Bags large rocks (at least enough for 350 mL per beaker)
- 4 Bags of colored sand (not water proof)

Standards Correlation Information

www.NEED.org/educators/curriculum-correlations/

Next Generation Science Standards

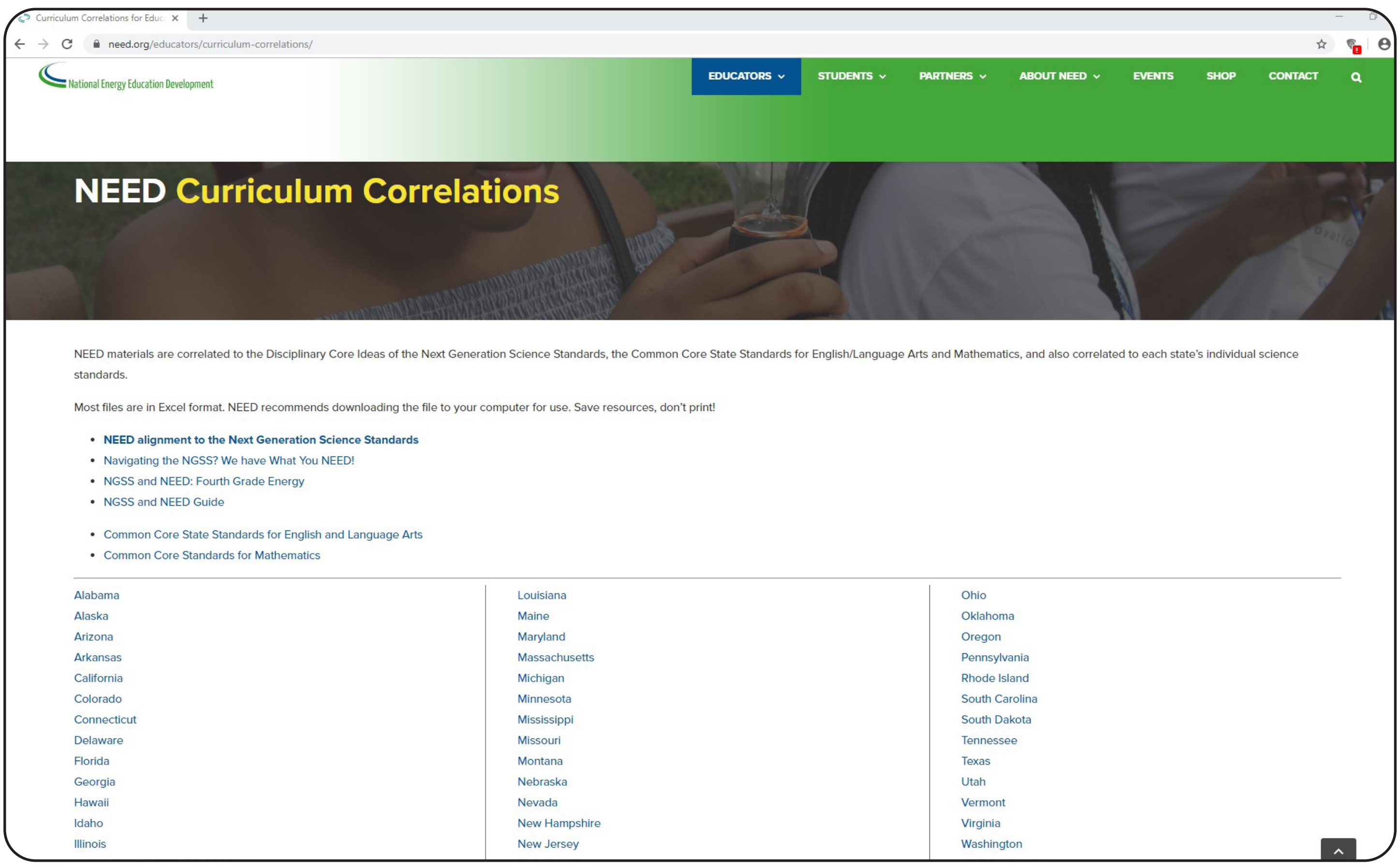
- This guide effectively supports many Next Generation Science Standards. This material can satisfy performance expectations, science and engineering practices, disciplinary core ideas, and cross cutting concepts within your required curriculum. For more details on these correlations, please visit NEED's curriculum correlations website.

Common Core State Standards

- This guide has been correlated to the Common Core State Standards in both language arts and mathematics. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED curriculum correlations website.

Individual State Science Standards

- This guide has been correlated to each state's individual science standards. These correlations are broken down by grade level and guide title, and can be downloaded as a spreadsheet from the NEED website.

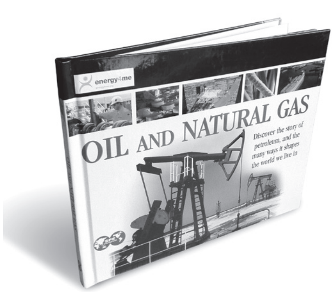


Exploring Oil and Natural Gas Materials

ACTIVITY	MATERIALS INCLUDED IN KIT	ADDITIONAL MATERIALS NEEDED
Formation of Petroleum and Natural Gas		▪Legal-sized paper ▪Colored pencils or markers
Chemical Models		▪Molecular model sets
Hydrocarbon Properties		▪Graph paper or computers
Exploring Polarity		▪Foam and biodegradable packing peanuts ▪Acetone ▪100 mL Beakers ▪Stirring rods ▪Safety goggles ▪Water
Fault Blocks		▪8" x 3" x 1" Wooden blocks ▪Candle or paraffin wax ▪Markers or crayons ▪Ruler ▪Sandpaper ▪Permanent markers ▪White paper
Mapping the Ocean Floor		▪Large smoothie-sized straws ▪White paper ▪Scissors ▪Tape ▪Markers of several different colors
Exploring Sound Waves	▪Metal slinky spring ▪Large foam cups ▪Small foam cups	
Core Sampling	▪3-4 Colors of sand ▪Clear plastic straws ▪Small opaque cups (bathroom sized)	▪Water in spray bottles ▪Plastic spoons ▪Rulers ▪Plastic containers ▪Soil or gravel (optional)
Exploring Porosity	▪600 mL Beakers ▪100 mL Graduated cylinders ▪Large rocks ▪Medium rocks ▪Small rocks ▪Food coloring (optional)	▪Water ▪Paper towels
Getting the Oil Out	▪Clear plastic straws	▪Cartons of chocolate milk or dark-colored beverage ▪Masking tape ▪Scissors ▪Rulers ▪Paper towels

ACTIVITY	MATERIALS INCLUDED IN KIT	ADDITIONAL MATERIALS NEEDED	
Perforated Well Casing	▪Pairs of kitchen sponges, the same size and shape ▪Flexible straws	▪Push pins ▪Shallow trays (for sponges) ▪Shallow trays (for collection from straws) ▪Plastic wrap	▪Heavy books or weights ▪10 - 25 mL Graduated cylinders ▪Water ▪Tape ▪Paper towels
Visualizing Hydraulic Fracturing	▪Cups or beakers	▪140 mL Syringes ▪Extra-large milkshake straws ▪Fracking boxes (see assembly) ▪Packing tape ▪Plastic wrap ▪Paper towels ▪Packages of dehydrated water beads (clear)	▪Breakfast syrup ▪Push pins ▪Rulers ▪Pitchers or large bowls (about 1 gallon capacity) ▪Water
Fracking Box Assembly Instructions		▪2 2″ x 36″ x ⅜″ Pine ▪1 36″ x 1″ x 1″ Square dowel ▪1 2′ x 2′ x ¼″ Plywood ▪1 2″ x 48″ x 1″ Pine ▪1 18″ x 24″ x ⅛″ Plexiglass ▪Waterproof wood glue ▪Tiny nails ▪2″ Finishing nails	▪Tiny drill bit ▪12″ x 6″ Fiberglass window screening ▪Clear silicone adhesive ▪Staple gun ▪Paint or sealant ▪½″ Drill bit ▪1″ Drill bit
Fracturing With Gelatin	▪Flexible straws	▪20 cc Syringes ▪Breakfast syrup ▪Plastic knife ▪Dinner plates ▪Large measuring cups ▪Loaf pans ▪Non-stick cooking spray	▪Plastic wrap ▪Push pins ▪Spatulas ▪Unflavored gelatin ▪Wire whisks ▪Water ▪Paper towels
Fracturing a Cake	▪Turkey injectors	▪Frozen layer cake ▪Chocolate Magic Shell® sundae topping ▪Plastic knives ▪Cups or beakers (optional)	
Understanding Density	▪Graduated cylinders ▪600 mL Beakers ▪Food coloring ▪Small corks ▪Pennies ▪Glass marbles ▪Wooden beads or wooden buttons	▪Corn syrup ▪Water ▪Vegetable oil ▪Plastic buttons ▪Grapes or blueberries ▪Ice cubes ▪Strainers (optional)	
Using Density to Extract Petroleum		▪500 mL Clear Erlenmeyer flasks ▪Two-hole #7 rubber stoppers ▪250 mL Beakers ▪30 cm Sections of vinyl tubing to fit rubber stopper	▪Vegetable oil ▪Water ▪Red oil-soluble dye ▪60 cc Plastic syringes ▪Petroleum jelly

ACTIVITY	MATERIALS INCLUDED IN KIT	ADDITIONAL MATERIALS NEEDED
Polymers	▪Small bathroom sized cups ▪Food coloring ▪Graduated cylinders	▪Cornstarch ▪Water ▪Sealable plastic sandwich bags ▪Measuring spoons ▪Food coloring ▪Paper plates ▪White glue ▪Borax ▪Spoons or popsicle sticks to stir ▪Rulers
Volume Simulations		▪Inflatable beach balls ▪Ping pong balls ▪Sets of 600 counting units (cotton balls, bingo chips, etc.) ▪1000 mL Beakers ▪Water
The Natural Gas Chain		▪String or yarn ▪Cardstock or poster board
A Nifty Natural Gas Story		▪Art supplies or props ▪Large, wooden kitchen matches ▪Regular flashlight and hand-generated flashlight
Careers in the Natural Gas Industry		▪Computers with internet access
Oil and Natural Gas Career Game		▪Dice
Peak Oil Game		▪¼ Teaspoons ▪½ Teaspoons ▪Teaspoons ▪Tablespoons ▪Long-handled spoons ▪Serving spoons ▪Bags of black beans ▪Bags of pinto beans ▪Jars ▪Digital balances ▪Paper ▪Notebooks ▪Timer with alarm ▪Small tubs or paper bags ▪Large tubs ▪Marbles or rocks
Road Trip		▪Internet access ▪Calculators



Oil and Natural Gas, from the Society of Petroleum Engineers, is a great resource that supplements the information and activities in *Exploring Oil and Natural Gas*. Available in several languages, this book showcases the geology, technology, careers, and difficult concepts of oil and natural gas in a fun, colorfully illustrated, and informational way.

To download the book or order a free classroom copy, visit http://www.energy4me.org/resouces/oil-and-natural-gas-book/.

Teacher Guide

Grade Levels

- Intermediate, grades 6-8
- Secondary, grades 9-12

Time

- Five to fifteen 45-minute class periods, depending on the activities selected

Additional Activities and Resources

NEED has several other guides and activities available at various levels to enhance your discussion about oil and natural gas. Download these guides and activities from shop.NEED.org.

- *Fossil Fuels to Products*—Fractional Distillation Game and Maze
- *Wonders of Oil and Natural Gas*—Petroleum Ponder
- *Energy on the Move*—Pretzel Power

Web Resources

- EIA Kids—www.eia.gov/kids
- Energy4Me—energy4me.org
- The Society of Petroleum Engineers—www.spe.org/en/

Introduction

At the conclusion of this unit, students will understand the formation, production, and uses of oil and natural gas. Activities illustrate the exploration, extraction, production, and processing of petroleum and natural gas, and introduce students to the many careers available in the oil and natural gas industries.

Unit Preparation

- Familiarize yourself with the information and activities in the guide.
- Select the activities you will use to introduce and reinforce concepts.
- Gather the kit materials and additional supplies needed for the activities you have chosen using the chart on pages 5-7. The activities are designed so that the additional materials required are inexpensive and are available in the school science lab, or can be obtained easily at hardware, pet, and craft stores. If you have difficulty locating any of the materials you need, please e-mail NEED at info@need.org for information on where you can purchase the materials.

Science Notebooks

Throughout this curriculum, science notebooks are referenced. If you currently use science notebooks or journals, you may have your students continue using them. A rubric to guide assessment of student notebooks can be found on page 33.

In addition to science notebooks, student worksheets have been included in the guide. Depending on your students' level of independence and familiarity with the scientific process, you may choose to use these instead of science notebooks. Or, as appropriate, you may want to make copies of worksheets and have your students glue or tape the copies into their notebooks.

Introductory Procedure

1. Have students create a KWL chart, or similar graphic organizer, entitled Oil and Natural Gas.
2. Have students read the *Student Informational Text* and take notes or add to their graphic organizer.

Classroom Management Options

- You may choose to have students read for homework.
- Break up the reading to fit with the activities you choose to do, and have students read sections as they are applicable.
- Complete the reading as a jigsaw activity where students read sections and share what they learned with the class or a small group.

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Activity 1: Formation of Petroleum and Natural Gas

Background

Petroleum is a mixture of hundreds of different hydrocarbons. Hydrocarbons are molecules containing hydrogen and carbon—that exist sometimes as a liquid (crude oil) and sometimes as a vapor (natural gas). Hydrocarbons are typically made from the remains of tiny sea plants and animals that died and were buried on the ocean floor for millions of years. Layer upon layer of the plant and animal remains built up. This pressure combined with heat from the Earth's processes slowly "cooked" the plant and animal remains into hydrocarbons. Finally, an oil-soaked rock—much like a wet sponge—was formed. These hydrocarbons flowed into empty spaces in the surrounding rocks, called traps. The traps were covered with a layer of solid rock, or a seal of salt or clay, that kept the oil and gas from escaping to the surface. Crude oil, or petroleum, is held inside the rock formation, similar to how a sponge holds water.

Objective

- Students will be able to describe the geologic processes that occurred to create oil and natural gas.

Time

- 1 class period

Materials

- Legal-sized paper, one sheet per student
- Colored pencils or markers
- *Formation of Petroleum and Natural Gas* story, page 67

Preparation

- Gather materials for students.
- Pick a portion of the class in which to conduct the activity so that no interruptions will occur. The objective is to help students improve their listening skills and visualize how oil and gas were formed.
- Make a copy of the worksheet for students (as needed).

✔ Procedure

1. Have students clear everything from their desks except pencils and any other art supplies.
2. Give each student a sheet of paper.
3. Instruct students to fold it in thirds (like a letter), and label the sections Scene 1, Scene 2, and Scene 3.
4. Tell the students you will be reading a story two times. The first time, they should just listen and try to visualize the scenes as you describe them. The second time, they will be illustrating the story, and you will be pausing frequently to give them time to draw.
5. Read the story one time all the way through.
6. Tell the students you are now going to read a second time, and instruct them to get ready to draw.
7. Read the story a second time, pausing frequently to allow students time to illustrate what you have read.

NOTE: It may be helpful to provide a copy of the story to students with auditory processing delays.

Activity 2: Chemical Models

Background

Petroleum and natural gas are made of hydrocarbons—molecules containing only hydrogen and carbon. Students will explore the various hydrocarbons often found in petroleum and natural gas.

Objectives

- Students will be able to construct models of simple saturated hydrocarbons.
- Students will be able to balance chemical equations.

Time

- 1-2 class periods

Materials

- Molecular model set for each group of students (three colors of modeling clay and toothpicks will also work as a substitute)
- *Chemical Models* worksheets, pages 68-71

Preparation

- Gather the materials needed, and make copies of student worksheets.
- Divide the students into groups of two or three, giving each group a modeling set.
- Review with students the process for balancing chemical equations.

✔ Procedure

1. Explain to the students that raw natural gas and crude oil are typically found as mixtures of compounds. These compounds are primarily hydrocarbons, consisting of only carbon and hydrogen atoms.
2. The gases found in raw natural gas are mostly simple alkanes, and the prefix of the name tells the number of carbon atoms in the longest chain.
3. Distribute the worksheets. Have students read the background information and look at the list of *Hydrocarbon Series Roots*. Ask the students if they have any questions and give them time to complete the *Molecular Formulas* section of the worksheet.
4. Discuss the answers to the *Molecular Formulas* section to ensure all students have the correct answers. Allow students time to complete the *Molecular Models* and *Balancing Equations* sections of the worksheet.
5. Review the equations to ensure correct answers. Allow students time to complete the *Hydrocarbon Combustion* section of the worksheet.

Extension

- Have students explain what impact burning hydrocarbons has on the environment.

Activity 3: Hydrocarbon Properties

Background

Hydrocarbons are chemically bonded carbon and hydrogen atoms. There are some intermolecular attractions that affect the properties of the compounds. In general, the larger the molecule, the greater the intermolecular attraction, and the more likely the compound is to be liquid or even solid at room temperature. However, increasing numbers of carbon-carbon bonds or carbon-hydrogen bonds represent an increasing amount of energy available per molecule.

Objective

- Students will be able to graphically illustrate the relationship between molecule size and physical properties of hydrocarbon compounds.

CONTINUED ON NEXT PAGE

Time

- 2-3 class periods, plus discussion

Materials

- Graph paper or computer per student
- *Hydrocarbon Properties* worksheets, pages 72-73

Preparation

- Make copies of worksheets for each student.
- If you are having students graph the data on computers, make sure students are familiar with using computer programs or spreadsheets to graph data.

✔ Procedure

1. Distribute the student activity pages to students, along with graph paper, if needed.
2. Review the names of hydrocarbons using pages 48-49 of the informational text and the *Hydrocarbon Properties* worksheets as background. Explain the relationship between the number of carbon atoms and the root of the name.
3. Have students complete the activity either on computers or by hand with graphing paper, and answer the questions.
4. Discuss the results of the activity with the students, pointing out which molecules are used for which primary purposes.

Activity 4: Exploring Polarity

Background

Foam packing peanuts are made from blow molded polystyrene, or Styrofoam™. The name Styrofoam™ is trademarked by the Dow Chemical Corporation. Although blow molded polystyrene is less dense than water, solid polystyrene has a density of about 1.05 g/cm^3 and will sink in water.

Starch packing peanuts are a natural material usually made from corn starch. The use of starch based packing peanuts started in the 1990s. Starch packing peanuts are biodegradable and non-toxic and will dissolve in water. The starch molecules are polar and contain hydroxyl (-OH) groups. These -OH groups bond with water molecules, and as a result the starch dissolves in water. Polystyrene has no hydroxyl groups and is nonpolar. Therefore polystyrene will not dissolve in water.

Polar substances dissolve in polar substances, and nonpolar substances will dissovle in nonpolar substances. When handling and transporting hydrocarbons, polarity is important.

✪ Objectives

- Students will be able to describe how polar and nonpolar substances interact.
- Students will explore the 'like dissolves like' principle to explain how to safely handle oil and natural gas.

Time

- 1 class period, plus additional time for work outside of class

Materials *PER GROUP*

- 2 Foam and 2 biodegradable starch packing peanuts
- Acetone
- 2 100 mL Beakers
- 2 Stirring rods
- Safety goggles
- Water

Materials *PER STUDENT*

- *Exploring Polarity* worksheet, page 74

CONTINUED ON NEXT PAGE

Preparation

- Gather materials. Have extra packing peanuts available. Store starch peanuts in an air-tight container to keep them from sticking together.
- Make a copy of the worksheet for each student.

✔ Procedure

1. Make sure students are always wearing safety goggles when working with organic solvents like acetone.
2. Review the hazards associated with acetone. Remind students of safe handling and disposal techniques for all solutions at the end of the activity.
3. Monitor students as they complete the activity.
4. Discuss the results of the activity with students. Be sure to highlight the differences between polar and nonpolar substances and how they interact and how it is important for handling hydrocarbons.

Activity 5: Fault Blocks

Background

Sedimentary rock is formed by the build up of layers of sand and sediment over time. Layers are formed through erosion, deposition, and compression of sediments. Sediments are transported by water in rivers, lakes, streams, and oceans, by ice in glaciers, and by wind. Over thousands and even millions of years, these particles are compressed through heat and pressure to create rock. Since sedimentary rock often has many pores, it is an ideal rock formation to contain or trap oil and natural gas. Geologists have classified petroleum traps into two basic types: structural and stratigraphic traps.

Structural traps are traps that are formed because of a deformation in the rock layer that contains the hydrocarbons. Three common examples of structural traps are fault traps, anticlines, and salt domes. Fault traps are created when rock layers (strata) crack and slide up or down past each other. The most common type of trap occurs when the fault slides a layer of impermeable rock across a layer of permeable rock through which oil and natural gas are migrating. The hydrocarbons are now trapped there.

Anticline traps are formed by the movement of Earth's crust. The strata bend up into an arch from the pressure at the sides. This is often called a fold. If one of these folded layers is impermeable, the oil and natural gas in layers below may seep up underneath and accumulate in the pores there. Anticline traps like this hold much of the world's oil.

Salt dome traps are formed when masses of salt form deep underground. Heat and pressure cause them to bulge upward in domes. The rising domes force the overlying rock layers aside. As they do so, they can cut across layers of permeable rock, blocking the path of any migrating hydrocarbons and create a trap.

Stratigraphic traps are created by variations within the rock layers themselves. A pinch-out is a common type of stratigraphic trap. Pinch-out traps are often formed from old stream beds, where a lens-shaped region of permeable sand becomes trapped within less permeable shale and siltstones.

✪ Objective

- Students will be able to explain how oil and natural gas get trapped beneath rock layers.

Time

- 30-45 minutes

Materials *PER DEMONSTRATION OR PER GROUP*

- 8" x 3" x 1" Wooden block
- Candle or paraffin wax
- Markers or crayons
- Ruler
- White paper
- Sandpaper
- Permanent markers
- *Fault Blocks* master template, page 44

Materials *PER STUDENT*

- *Fault Blocks* worksheet, page 75

CONTINUED ON NEXT PAGE

Preparation

- Use the *Fault Blocks* master template to cut an 8" wooden block into three pieces.
- Use sandpaper to smooth all rough edges.
- Lay the 3 pieces down together and use the ruler to divide the assembled block into three horizontal rock layers approximately one inch wide. Each layer should be filled in with a different color using markers (permanent or regular).
- Rub a candle or block of paraffin on the edges of each piece. The pieces will be pushed together to show the faults.
- Make a copy of the worksheet for each student.

✔ Procedure

1. Distribute the activity to the students. If you've prepared several sets of blocks, students can work in groups.
2. Go over the background information with students.
3. Review how rock layers are formed, and separated at fault lines, with students, and how these processes are significant for oil and gas formation.

Activity 6: Mapping the Ocean Floor

Background

Because of the age of the rocks in which petroleum and natural gas were formed, looking in the right locations in the vast oceans is important. This activity is designed to acquaint students with the way a spreading sea floor is formed, and how the depth of the ocean floor or crust is related to the age of the rocks beneath it.

If you wish your students to work in pairs or small groups, an alternative method would be to push two desks or tables together, and feed the paper strips up from beneath the tables through the crack between them. This method eliminates the need for straws and tape.

✪ Objective

- Students will be able to describe how the depth and age of rock layers help geologists find oil and gas.

Time

- 1-2 class periods

Materials *PER STUDENT*

- 2 Large smoothie-sized straws
- White paper
- Scissors
- Tape
- Markers of several different colors
- *Mapping the Ocean Floor* worksheets, pages 76-77

Preparation

- Gather materials for students. Each student or group of students will need at least 3 or 4 different colors of markers.
- Make copies of the worksheets for each student.
- It might be helpful to project the maps on the *Mapping the Ocean Floor* worksheet, or have color copies available for students so they can see the subtle shading to adequately answer the questions. A color copy of the maps can be found on NEED's Awesome Extras page or in NEED's online image gallery. Visit www.NEED.org/oilandgasmaterials or https://need-media.smugmug.com/Graphics/petroleum/.

✔ Procedure

1. Distribute the activity. Review the way plates move apart and how new rock is forced up from below in the Atlantic Ocean.
2. Project or circulate a color copy of the maps if necessary.
3. Review student responses and be sure to discuss where students think the best spots to look for oil and natural gas might be.

Activity 7: Exploring Sound Waves

Background

There are two different types of waves: transverse and longitudinal. Electromagnetic radiation, such as sunlight or radio waves, travels in transverse waves. A transverse wave is one with oscillation that is perpendicular to the direction of travel. A longitudinal wave, however, oscillates in the same direction in which it travels. Sound travels in longitudinal waves like seismic waves travel underground. Because of this property, seismic waves can be used to locate oil and natural gas resources.

This activity will demonstrate to your students how a spring models the movement of longitudinal waves, and how the reflection of longitudinal waves helps oil producers locate areas in which petroleum and natural gas might be found. In this activity, sound waves from the spring represent the reflected seismic wave motion geologists measure when exploring for oil and natural gas.

Objective

- Students will be able to demonstrate how longitudinal waves travel and describe how they can be helpful for oil and natural gas exploration.

Time

- 1 class period

Materials *PER GROUP*

- 1 Metal slinky spring
- 1 Large foam cup
- 1 Small foam cup

Materials *PER STUDENT*

- *Exploring Sound Waves* worksheet, page 78

Preparation

- Gather materials for students.
- Make a copy of the worksheet for each student.

✔ Procedure

1. Clear an area for students to work that is free from obstructions, furniture, etc.
2. Students need to work in small groups of two or three for this activity to be most successful.
3. Distribute the activity, and remind students to be cautious NOT to tangle their springs.
4. Discuss student results, conclusions, and how sound waves might be useful for exploration.

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Activity 8: Core Sampling

Background

Core sampling is used in a wide variety of applications when it is difficult or impractical to dig down and expose layers of ice or rock when exploring for petroleum and natural gas. Core samples can be removed and observed visually to find the porous rock most likely to contain desired resources.

This activity simulates how layers of sediment are deposited year after year, and shows students how geologists interpret a core sample when looking for petroleum or natural gas.

Objective

- Students will be able to describe how a core sample can help geologists interpret rock layers and find oil and natural gas formations.

Time

- 1 class period

Materials *PER GROUP*

- 3-4 Containers of sand (different colors)
- Water in spray bottles
- Plastic spoons
- Ruler
- Container of soil or gravel (optional)
- Paper towels, plastic bags, or table cloths (optional)

Materials *PER STUDENT*

- 1 Clear plastic straw
- 1 Small opaque cup (bathroom sized)
- *Exploring Core Sampling* worksheet, page 79

Preparation

- Gather all materials. Pour each bag of aggregate into smaller containers for each group.
- It can be helpful if you provide several containers of each material for students to share, so they're not waiting a long time for any given material to construct their sampling cups.
- Students may layer materials in any order. It is not necessary for each layer to be exactly one centimeter deep.
- This activity can be messy. It is recommended to have paper towels, plastic bags, or even table cloths on hand.
- Make a copy of the worksheet for each student.
- Pre-assign student partners for trading core sample cups. If you have an odd number of students, arrange a 3-way trade.

✔ Procedure

1. Distribute the activity and discuss the instructions for set-up.
2. As students proceed through the activity, monitor their progress to make sure they're not getting their materials too wet.
3. Discuss student results and challenges with the class, and ask students to connect their results and challenges to those that might be facing geologists in the exploration process.

Activity 9: Exploring Porosity

Background

One property used to describe rocks is porosity. Porosity describes the number of tiny open spaces or pores contained within a rock. The porosity of a rock is important. If a rock layer is not porous enough, liquids cannot be held or trapped there. Rocks that are good for oil and natural gas have higher porosities, but also have permeability, allowing oil and gas to move from pore to pore, through the rock. This activity demonstrates to students how materials of various porosities can trap fluids.

Objective

- Students will be able to describe how porosity of a rock layer is important for oil and natural gas exploration and production.

Time

- 1 class period

Materials *PER GROUP*

- 3 600 mL Beakers
- Water
- 100 mL Graduated cylinder
- Large rocks
- Medium rocks
- Small rocks
- Paper towels
- Food coloring (optional)

Materials *PER STUDENT*

- *Exploring Porosity* worksheet, page 80

Preparation

- Gather all materials.
- Add food coloring to the water, if necessary, to make it easier to see during the activity.
- Make a copy of the worksheet for each student.
- It may be helpful to set up an area with towels or strainers to drain or dry the aggregate when finished.

✔ Procedure

1. Before students begin the activity, caution them about dropping marbles or coarse gravel into a glass beaker so they don't break the glass.
2. Distribute the activity and be sure students understand the instructions.
3. Provide a place for students to dump their wet materials to drain and/or dry when they have finished the activity.
4. Discuss porosity with the class and how it is important to the exploration and production process using student observations.

Activity 10: Getting the Oil Out

Background

Due to the location of the well and the conditions under the surface, some wells have natural pressure pushing the liquids to the surface. Some wells do not have this natural pressure to produce the oil and bring it to the surface. Students will explore the relationship between depth and pressure and the challenges engineers face trying to "produce" materials, or bring them to the surface.

Objective

- Students will be able to describe the relationship between well depth and effort to recover resources.

Time

- 1 class period

Materials *PER GROUP*

- 8-10 Clear plastic straws
- 8 oz. Carton of chocolate milk or dark-colored beverage of a lower viscosity
- Masking tape
- Rulers
- Scissors
- Paper towels

Materials *PER STUDENT*

- *Getting the Oil Out* worksheet, page 81

Preparation

- Gather all materials.
- Make a copy of the worksheet for each student.
- Keep paper towels on hand for spills. It's easy to tip a carton or cup of chocolate milk over with the straw apparatus.

✔ Procedure

1. Distribute the activity. Discuss with students that it may be necessary to have a partner stabilize the container of beverage, as it may easily tip.
2. Have a place for students to dispose of their beverage when the activity is complete.
3. Discuss student results and encourage them to think about and identify the challenges of deep well drilling based on their results.
4. Have students discuss how viscosity or other variables might impact their results. Allow them to experiment with liquids of varying viscosities, if time allows.

Extension

- Conduct the activity as a STEM challenge, providing students with various materials and a prompt to produce the most liquid from their reservoir in a specified amount of time.

Activity 11: Perforated Well Casing

Background

Once a well has been drilled, the well casing becomes perforated by explosive charges. Perforating oil and natural gas wells allows the fluids to flow more easily into a well by creating multiple openings rather than just one opening at the end of the casing. When recovering resources horizontally from tight formations, like shale with many tiny pores, these perforations also allow fluids to travel out into the formation. These fracturing fluids create fissures to release the tightly held oil or gas in the formation, allowing it to flow. This horizontal drilling method, coupled with perforating the well casing, increases the productivity of a well, often by three to five times.

Objective

- Students will be able to explain the importance of perforation in the process of drilling.

Time

- 1 class period

Materials *PER GROUP*

- 2 Kitchen sponges, the same size and shape
- Several flexible straws
- Push pin
- Shallow tray (for sponges)
- Shallow tray (for collection from straw)
- Plastic wrap
- 1-3 Heavy books or weights
- 10 - 25 mL Graduated cylinder
- Water
- Tape
- Paper towels

Materials *PER STUDENT*

- *Perforated Well Casing* worksheets, pages 82-83

Preparation

- Gather materials for the activity.
- Make copies of the worksheets for each student.
- Have plenty of paper towels for clean up afterwards.

✔ Procedure

1. Distribute the activity and explain the instructions.
2. Discuss how perforations improve the results of the drilling process.

Extension

- Give students time and alternative materials to allow them an opportunity to improve the model to make it more realistic, to isolate variables, or to produce more fluid.

Activity 12: Visualizing Hydraulic Fracturing

Background

Hydraulic fracturing can be difficult to visualize. This set-up aims to demonstrate how fluid moves during the process of fracturing. The gel beads are used because, when placed in the box, they have openings between them to simulate pores, and can also demonstrate the movement of fluid through these pores. This activity, as it requires construction and can be messy, is very well served as a demonstration. In many cases, results can be variable. As a STEM challenge, allow students an opportunity after the demonstration to design and engineer their own mediums and set-ups to fracture in order to create the best visualization and movement of fluid.

Objective

- Students will be able to describe the process of hydraulic fracturing and why the process is used.

Time

- 1 class period (not including box assembly)

Materials *PER GROUP*

- 140 mL Syringe
- Extra-large straw (milkshake-sized straws work well–20 cm long, 1 cm diameter)
- Fracturing box
- Packing tape
- Plastic wrap
- Paper towels
- 1 Package dehydrated water beads (clear), prepared per instructions
- 125 mL Breakfast syrup
- Push pin
- Ruler
- Pitcher or large bowl (about 1 gallon capacity)
- Water
- Cup or beaker
- *Fracturing Box Assembly Instructions*, pages 86-87

Materials *PER STUDENT*

- *What is Hydraulic Fracturing?* article, pages 65-66
- *Visualizing Hydraulic Fracturing* worksheets, pages 84-85

Preparation

- See the notes on preparing the fracturing box on pages 86-87. Construct the box or boxes you will need for your class.
- Prepare and hydrate the gel beads at least 6-8 hours prior to the activity, using water and a pitcher. Follow package instructions.
- Make copies of the article and worksheets for each student.

✔ Procedure

1. Review the informational text insert with students.
2. Set up and carry out the visualization activity, while students complete their worksheets. It may be helpful to have a student video the demonstration while it is occuring, so that students may see it again and again to draw conclusions.
3. Discuss how the fluid moved and what problems exist with this system as a model. Ask the class for suggestions to improve this system as a model, and experiment. How might these difficulties relate to the actual process of hydraulic fracturing?

Extension

- Allow students time to re-design the model to create a better visualization of fracturing and fluid movement. Have students construct their models and discuss how the redesign differs from and improves upon the demonstration version.

Activity 13: Fracturing With Gelatin

Background

This activity aims to demonstrate how fracturing fluid, at high pressure, is able to create a fissure in the rock layer. Students will be able to see the syrup come out at a high velocity to crack the gelatin. The gelatin, however, will not hold the syrup within like rock layers and other materials will. Discuss with students how this activity can be re-modeled.

Objective

- Students will be able to describe the process of hydraulic fracturing and why the process is used.

Time

- 1 class period

Materials *PER GROUP*

- 20 cc Syringe (oral dosing syringe works well)
- 50 mL Breakfast syrup
- Plastic knife
- 1 Dinner plate
- 1 Flexible straw
- Plastic wrap
- 1 Push pin
- Paper towels
- Warm water

Materials *FOR GELATIN*

- Non-stick cooking spray
- Spatula
- Unflavored gelatin
- Wire whisk
- Water
- Large measuring cup
- Loaf pan

Materials *PER STUDENT*

- *Fracturing With Gelatin* worksheets, pages 88-89

Preparation

- Gelatin blocks can be prepared the night before the activity or even further ahead of time and refrigerated until used in class. The instructions below can prepare 2-3 blocks of gelatin. Adjust the recipe to accommodate more students if needed.
- Prepare gelatin blocks using the following instructions:
  - Fill the large measuring cup with ½ cup of water.
  - Sprinkle 3 packets of gelatin over the water and swirl to mix.
  - Add boiling water to the gelatin to fill to four cups. Whisk to dissolve the gelatin.
  - Spray the bottom of the loaf pan with cooking spray and pour the hot gelatin solution into the loaf pan.
  - Refrigerate overnight.
- Make copies of the worksheets for each student.
- Gather materials for students.
- Have paper towels and warm water available for syrup spills.

✔ Procedure

1. Cut the gelatin into blocks and, using the spatula, distribute blocks to student groups.
2. Discuss the activity and instructions with students.
3. Discuss how the fractures formed in each block and what the syrup did as a result. Connect student observations to the process of fracturing.
4. Ask students to consider and discuss other materials and liquids to attempt "fracturing" into.

Activity 14: Fracturing a Cake

Background

This activity aims to demonstrate how fracturing fluid can be held in the pores of rock, once fissures are created. The Magic Shell® topping can move from pore to pore and spread out—the cake has permeability. As the fluid is exposed to the temperature of the cold cake it hardens. This resembles the way fracturing fluid moves into pores and then holds them open with coagulants that allow the natural gas to flow through them. Students may notice that the fluid (Magic Shell®) did not travel into the icing between layers. These layers of icing represent impermeable layers of rock of different density and porosity. Oil, natural gas, and fracturing fluid cannot flow or seep through layers that are impermeable.

Objective

- Students will be able to describe the process of hydraulic fracturing and why the process is used.

Time

- 20-30 minutes

Materials *PER GROUP*

- 1 Piece of frozen layer cake
- 1 Turkey injector
- Chocolate Magic Shell® sundae topping
- 1 Cup or beaker (optional)
- 1 Plastic knife

Materials *PER STUDENT*

- *Fracturing a Cake* worksheets, pages 90-91

Preparation

- Make or purchase a layer cake and freeze it. Pre-prepared frozen layer cakes work very well.
- Gather additional materials for students.
- Make copies of the worksheets for each student.
- Cut the frozen cake into pieces for your students so that each student or pair has an iced end into which they will fracture.

✔ Procedure

1. Distribute materials. Assemble turkey injectors for students ahead of time, if need be.
2. Remind students to keep their sundae topping moving around in their cup or beaker, or it will harden.
3. Review student observations and discuss how the fracturing fluid (sundae topping) did or did not move throughout layers of the cake.

Activity 15: Understanding Density

Background

Objects will float or sink in a liquid according to their density. If an object is more dense than a liquid, it will sink; if it is less dense, an object will float. This activity sets up a column of liquids with different densities, and the objects listed will arrange themselves by density (see photograph below). Density is important to oil and natural gas production. The fluids retrieved from a well often contain a mixture of petroleum, natural gas, water, and other impurities. Heat and density are used to separate useful materials from unwanted materials and hydrocarbons for processing.

Objectives

- Students will be able to compare densities of different items.
- Students will be able to define density and describe its importance as a physical property.

Time

- 1 class period

Materials *PER GROUP*

- Graduated cylinder
- 600 mL Beaker
- Corn syrup
- Water
- Vegetable oil
- Food coloring
- Plastic button
- Grape or blueberry
- Small cork
- Penny
- Glass marble
- Wooden bead or wooden button
- Ice cube
- Strainer (optional)

Materials *PER STUDENT*

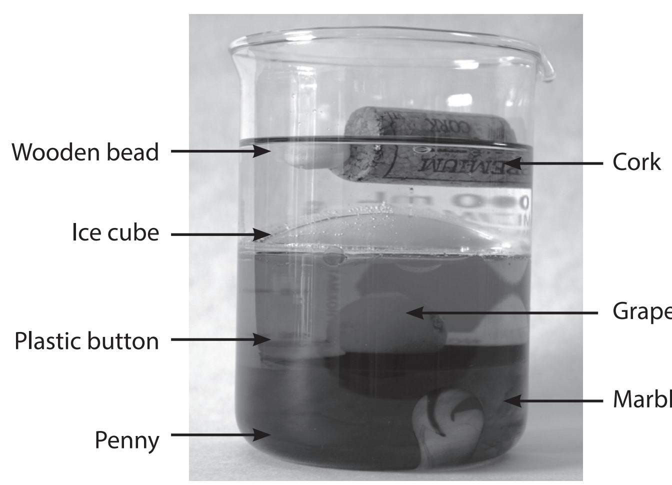
- *Understanding Density* worksheet, page 92

Preparation

- For efficiency and enhanced results, mix food coloring into the corn syrup and water the night before the activity.
- Students can bring their own materials or suggest others not listed in the activity. Have them predict where in the density column each object will be.
- Gather materials for students.
- Make a copy of the worksheet for each student.

✔ Procedure

1. Have students complete the activity as written, then drop other objects they have brought, or have found around the room, if time permits. The diagram on the right illustrates the projected results.
2. Provide a place for students to properly dispose of the liquids, grape, and ice cube. They might need a spoon to help them scoop out the very viscous corn syrup. The button, cork, marble, and penny can be washed with detergent and warm water.
3. Discuss student results. Ask students to ponder how density might relate to petroleum production to introduce the next activity.



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Activity 16: Using Density to Extract Petroleum

Background

Once oil producers are confident they have found the right kinds of underground rock formations, they can begin drilling production wells.

When a new petroleum field first begins producing petroleum, the natural pressures in the reservoir force the petroleum through the rock pores, into fractures, and up production wells. This natural flow of petroleum is called "primary production." It can go on for days or years. Over time, however, a petroleum reservoir begins to lose pressure. The natural petroleum flow begins dropping off and petroleum companies must use pumps or artificial lift to bring the petroleum to the surface.

It is not uncommon for natural gas to be found along with the petroleum. Petroleum companies can separate the gas from the petroleum and inject it back into the reservoir to increase the pressure and keep the petroleum flowing. This is called gas drive. Sometimes, however, this is not enough and a lot of petroleum will be left behind in the ground. Secondary recovery is then used to increase the amount of petroleum produced from the well.

Imagine spilling a can of oil on a concrete floor. You would be able to wipe some of it up, but a thin film of oil might be left on the floor. You could take a hose and spray the floor with water to wash away some of the oil. This is basically what petroleum producers can do to a petroleum reservoir during secondary recovery. They drill wells called "injection wells" and use them like gigantic hoses to pump water into a petroleum reservoir. The water with a different density washes some of the remaining petroleum out of the rock pores and pushes it through the reservoir to production wells. This is called "waterflooding."

Objective

- Students will be able to describe how density differences can be utilized to help retrieve petroleum resources.

Time

- 1-2 class periods

Materials *PER GROUP*

- 500 mL Clear Erlenmeyer flask
- Two-hole #7 rubber stopper
- 250 mL Beaker
- 2 30 cm Sections of vinyl tubing to fit rubber stopper
- 150 mL Vegetable oil
- 350 mL Water
- Red oil-soluble dye
- 60 cc Plastic syringe
- Petroleum jelly

Materials *PER STUDENT*

- *Using Density to Extract Petroleum* worksheet, page 93

Preparation

- Gather materials for students.
- Make a copy of the worksheet for each student.

✔ Procedure

1. Share the background information with students. Then have them complete the activity.
2. When students are finished, provide an appropriate place for disposal of the liquids.
3. Discuss the activity with the class, highlighting the parts of the set-up and how they relate to retrieving oil from the ground.

Extension

- Ask students to design an experimental set-up that models gas drive.

Activity 17: Polymers

Background

During the refining process, petroleum undergoes a process known as fractional distillation. Polymers are created from the products of this process. Polymers are formed when small molecules are bonded in a repeating pattern. The two polymers made in this activity use no hazardous solvents or chemicals and are safe for students.

Objective

- Students will be able to identify the properties of polymers.

Time

- 1-2 class periods

Materials *PER GROUP*

- Cornstarch
- Water
- Sealable plastic sandwich bags
- Measuring spoons
- Food coloring
- Paper plates
- White glue
- Borax
- Spoon or popsicle stick to stir
- Small bathroom sized cups
- Food coloring
- Graduated cylinder
- Rulers

Materials *PER STUDENT*

- *Polymers* worksheets, pages 94-95

Preparation

- Gather materials.
- Make a borax solution by dissolving 6 mL measured Borax in 235 mL of water.
- When conducting this activity, students may get glue on their hands and table top. If necessary, cover tables or desks with newspaper or table cloths and have a place where students can wash their hands when they're finished with the activity.
- Make copies of worksheets for each student. Only copy the worksheets your students will be using, based on how you choose to complete the activities.

✔ Procedure

1. Discuss the hazards of borax solution with students. This solution may irritate the skin or eyes. Borax should not be inhaled or swallowed.
2. Students can complete both polymers activities, or you may have students complete one or the other and share with a group who completed the other polymer activity.
3. Collect all polymer samples from students when the activity is complete. Make sure they have a place to properly dispose of all solutions and products of this activity.
4. Discuss the properties of polymers and their importance with the class.

Activity 18: Volume Simulations

Background

After oil and natural gas are separated they are transported for further processing and use. If natural gas must travel a long distance it can be liquefied from its gaseous state. When it is cooled to turn into a liquid it takes up less space, making it easier to transport for long distances. We call liquefied natural gas LNG.

Objectives

- Students will be able to explain how volume changes when a substance is changed from a gaseous state to a liquid state, and vice versa.
- Students will be able to quantitatively describe the volume difference between natural gas and LNG.

Time

- 30 minutes

Materials

- Beach ball
- Ping pong ball
- 1 Set of 600 counting units (or any item such as cotton balls) for each group
- 1 800-1,000 mL Beaker for each group
- Water

Preparation

- Gather the materials above.
- Divide the students into groups of three to five.
- Fill each beaker with 1 mL of water.

✔ Procedure

1. Show the students the beach ball and the ping pong ball. Ask them which ball they think represents natural gas and which represents LNG. The beach ball represents a gaseous state [natural gas] while the ping pong ball represents the liquid state [LNG]. Ask students to write and explain their reasoning.
2. Explain to the students that natural gas is typically found in a gaseous state. Explain that natural gas can be changed into a liquid (LNG) by making it very cold (-260°F or -162.2°C).
3. Ask the students what happens to the volume of a gas when it becomes a liquid. (The volume of a gas is reduced when it is a liquid.)
4. Revisit the ping pong ball and beach ball. Ask students to edit their reasoning from before, as necessary.
5. Pass out the 600 unit sets, one per group. Allow time for the students to determine how many units are in each set. Ask the students to predict the volume of natural gas in a liquid state (LNG) if the whole set represents a gaseous state. Have the groups set aside the number of units they predict.
6. Gather predictions from the groups and write them on the board or interactive board.
7. Explain to the students that LNG is 1/600th of the volume of natural gas in a gaseous state. Have the students separate out the correct number of units to represent LNG. (One unit) Collect the unit sets from the groups.
8. Pass the beakers with 1 mL of water to each group. Have the students predict or draw a line on the beaker (with pencil) to show how much water would represent natural gas in a gaseous state, if the amount of water presently in the beaker represents LNG. (600 mL) Collect the beakers.

Extensions

- Have students create additional visual natural gas and LNG volume comparisons and demonstrate them.
- Have students list possible advantages and disadvantages to natural gas in both a gaseous state and a liquid state.

Activity 19: The Natural Gas Chain

Background

When students think of energy, they most often are thinking of electricity; however, a significant proportion of the total energy in the U.S. is supplied by natural gas, and as more natural gas is unlocked from shale deposits, that proportion will continue to increase. The purpose of this activity is to help students understand how natural gas is used in the energy industry and how we can use it as consumers. Students will also identify the energy transformations of natural gas from formation to end use. Students will be able to describe how liquefaction helps in the storage and transport of natural gas. Students will be able to identify ways natural gas is used, produced, and safely handled, and be able to discuss careers directly involved in the natural gas industry.

Objectives

- Students will be able to list and describe the different steps needed to produce natural gas and bring it to market.
- Students will be able to provide examples of how a global natural gas system can be affected by one weak link in the chain.

Time

- 2 class periods, plus homework

Materials

- *Natural Gas Production to Market* master, page 96
- *Natural Gas as a System Hangtags*, pages 97-98
- *The Natural Gas Chain* worksheet, page 99
- String or yarn (in balls)

Preparation

- Make copies of the worksheets for each student.
- Prepare a copy of the *Natural Gas Production to Market* master.
- Cut out the hangtags. Fold each on the dotted line. Punch a hole through the folded card, and attach string so that a student may wear it around his or her neck. Assemble multiple sets to fit the number of students in the class, if necessary.
- Divide the students into groups of ten.

✔ Procedure

NATURAL GAS PRODUCTION TO MARKET

1. Explain to the students that natural gas is typically found in a gaseous state.
2. Ask students what they think happens to a resource when it is found far from cities or industries that use the resource. Is it helpful to customers? (Known as stranded resources, natural gas located in undesirable locations can be transported via pipeline to marketable locations.)
3. Have students review the *Natural Gas Production to Market* master and write information about each step on a sheet of paper, or provide a copy of the master for each student and assign as homework.

NATURAL GAS AS A SYSTEM

1. Distribute the system hangtags to the students, providing one set to each student group.
2. Ask students to read the backs of their cards and review their *Natural Gas Production to Market* information. Allow time for questions about roles or the process involved. It may be helpful to project the master briefly.
3. Have each group put on their hangtags and stand in a circle with one student holding the ball of yarn.
4. Explain that the first students should look around the circle and identify a part of the system that relates to his/her component. Have the first student hold onto one end of the yarn, say the name of the related component, and toss the ball of yard to that student. The first student then explains how their parts are related.

CONTINUED ON NEXT PAGE

5. Have the groups repeat the process until all students have caught and tossed the ball of yarn. In the end, there will be a web of yarn connecting all students in the group. In some cases, students may need to catch the ball of yarn twice.
6. Have one student give a tug on the string. Ask the students that felt the tug to explain how a stress on one component affected their role card. For example, a Production tug might cause an attached Processing tag to say, "If production of natural gas falls, the processing facility cannot distribute enough natural gas to residences to keep them warm."
7. Continue this process with each student tugging and suggesting different ways the system could be affected. Students should be able to explain various ways a change in one part of the system might affect other parts in the system. Students should also be able to identify ways the chain could be assembled differently and explain why.

THE NATURAL GAS CHAIN

1. Distribute copies of *The Natural Gas Chain* worksheet to each student.
2. Explain that each student should choose one step in the natural gas chain and write it in the center circle. The outside circles should be labeled with the nine remaining steps.
3. Have students write inside the arrow a way the inner component affects the outside one and a way the outer component affects the inner one. Assign as homework if students do not finish in class.

Activity 20: A Nifty Natural Gas Story

Background

Students will explore the energy transformations associated with a natural gas energy flow - from formation to end use.

Objective

- Students will be able to explain the energy transformations or flows involved with natural gas, from production to use.

Time

- 1-2 class periods

Materials

- Props and/or art supplies as listed
- *A Nifty Natural Gas Story* master, pages 100-101
- *A Nifty Natural Gas Story Pantomime*, page 102
- Large wooden kitchen matches
- Regular flashlight and hand-generated flashlight

Preparation

- Make a copy of *A Nifty Natural Gas Story Pantomime* for each student.
- Provide art supplies for students to assemble their props, or gather the suggested items or reasonable substitutes as shown on the handout.
- Prepare a copy of the story master to project.

✔ Procedure

1. Review or introduce energy by lighting a wooden match and asking students what is happening in energy related terms. Review the forms of energy on page 45 to assist in discussion.
2. Demonstrate a regular battery-powered flashlight and a hand-generated flashlight. Ask students to explain the energy transformations involved in the operation of each.
3. Assign students to a specific role on the pantomime sheet.

CONTINUED ON NEXT PAGE

4. Discuss how natural gas is produced, processed, transported, and used. Talk about the forms of energy being transformed in each step.
5. Have each student assemble his/her props, or provide each student with a suggested prop.
6. Review or introduce any new vocabulary as needed. Project the story. Act out the story from beginning to end. Extra students may help read the story aloud.
7. Substitute in different students or props as necessary.
8. Ask students to write an essay explaining the energy flow involved to produce electricity from natural gas.

Extensions

- Have students substitute different energy sources into the energy flow, creating a new story, props, and outcome for each.
- Have students brainstorm the transformations occuring in compressed natural gas or liquefied natural gas vehicles.
- Discuss the similarities and differences between thermal power plants (natural gas, biomass, coal, etc.) and other plants (nuclear, hydro, wind, etc.).

Activity 21: Careers in the Natural Gas Industry

Background

There are many careers associated with the natural gas industry. Through this activity, students will get aquainted with careers related to natural gas and develop résumés for the careers using the popular digital format, LinkedIn™.

Objective

- Students will be able to identify and describe careers in the natural gas and energy industries, and list skills and qualifications for each job description.

Time

- 1 class period, plus homework

Materials

- Computers with internet access
- *Careers in the Natural Gas Industry*, page 103
- *Career Networking Template*, pages 104-105

Preparation

- Make a copy of the template and career list for each student, or provide a digital copy to project or share with students.

✔ Procedure

1. Have students research some careers in the natural gas and energy industries. A list is found on page 103.
2. Allow students time to research other careers that are not listed. Ask students to select a career they would like to research further or might have an interest in.
3. Explain to students that they will be constructing a career profile, much like a digital résumé used in online networking sites for employment.
4. Instruct students to create a profile using the basic information requested on the template. You may wish to specify more or less items depending on the depth of the profile you might like them to complete. Profiles can be created on paper or using a software of your choice.

NOTE: Many career opportunities in the natural gas industry can overlap with the petroleum/oil industry. If students want to focus on a petroleum specific career field instead, refer them to the games on page 106 and 109-114.

Activity 22: Oil and Natural Gas Career Game

Background

Students are assigned to be either a drop of oil or a molecule of natural gas. As they move through the game, they encounter descriptions of many different types of people and their basic job responsibilities. The path starts with exploration and ends with end-use products.

Objective

- Students will be able to list and describe careers and opportunities in the oil and natural gas fields.

Time

- 1 class period

Materials

- Dice (one die per group)
- Cardstock or poster board
- *Oil and Natural Gas Career Game* board, page 106

Preparation

- Print copies of the game board on cardstock, or print and paste each copy onto poster board. One game board will be needed for each group of students. To print a color copy of the game board, download this guide at shop.NEED.org.

✔ Procedure

1. Have students cut the game pieces from the board.
2. Students will take turns rolling the die and moving through the game board.
3. Discuss the various careers students landed on, and what processes they were a part of.

Activity 23: Peak Oil Game

Game Goal

This game simulates the production challenges experienced during the life of a well and processing challenges when refining product. Teams are told that the team that recovers and processes the most oil in the 10 year period is the winner. This will motivate them to try hard and makes the activity fun, but this goal doesn't have much to do with the real educational goals, as the students will see later.

To start—each team begins with one person as 'driller' and one person as 'processor'. Each team has a set of jars (oil field), a small spoon, and 3 containers (1 for processing oil, 1 for refined oil, and 1 for accumulated oil).

The jars contain black beans (oil), pinto beans (dirt, contaminate), and rocks or marbles. These jars are their 'oil field.' They can mine the oil from any jar in any order. The 'oil' gets more and more diluted toward the bottom of the jars, so they produce less and have to do more processing as they go deeper. Also, there may be obstacles in bottoms of jars, like rocks. They cannot move the jars, pick up the jars, lean the jars over, use their fingers to extract beans, or pull out the rocks. They are limited to using their spoons to scoop beans out of the jars.

Each round of the timer (30 seconds to 1 minute) is one 'year.' During each 'year', the goal is to get as much clean oil into the team's 'refined oil' container as possible. Penalties are charged for contaminated oil and for beans (of any kind) spilled outside the containers. Each team also has a bag, box, or tub that they can use as a 'processing plant' in which to separate the beans. The processing must take place along with the drilling and stop after the timer goes off. For a quicker introduction to the game and its rules, download the Peak Oil Game PowerPoint from, www.NEED.org/oilandgasmaterials.

CONTINUED ON NEXT PAGE

When the timer goes off, all activity stops immediately and the following things happen (in order):

1. Penalties are assessed.
   - Dirt in the clean, refined oil container: For each pinto bean in the refined oil container, remove two black beans. Also remove the pinto beans.
   - Spilled oil: For each black bean or pinto bean spilled outside any of the containers, remove two black beans from the refined oil container (these amounts can be estimated rather than having to make exact 'bean counts'). Groups should aim to have zero beans spilled.
   - Obstacles, like rocks and marbles, may *not* be removed from the jars.
2. Discard all spilled and unprocessed oil into the communal waste container.
3. Measure the year's production. Weigh, or count, the beans that remain in the clean container after the penalties and record that year's production in the team's notebook. Also record any penalties assessed in this year.
4. Place the current year's harvest into the team's accumulated oil storage container. They will use this stored oil to purchase tools and labor (employees).
5. Buy better tools and hire more staff. Teams use their accumulated inventory of oil as cash to buy new equipment and hire people. Set prices for either a new state-of-the-art tool or hiring a new employee. After each round, the instructor announces any changes in prices, the latest technology and its current price, which should rise or fall as the technology changes.

The game should continue for about '10 years'—depending on the interest level of students. It's important to play enough rounds or 'years' so that each team's production has started to decline.

NOTE: If scales are not available, students may count the beans. The purpose of weighing is to account for the potential variance in bean size.

✪ Objectives

- Students will be able to describe possible production challenges faced over the life of a well.
- Students will be able to identify the peak production period for a well.

Time

- 1-2 class periods

Materials *PER GROUP*

- ¼ Teaspoons
- ½ Teaspoons
- Teaspoons
- Tablespoons
- Long-handled spoons
- Serving spoons
- Bags of black beans
- Bags of pinto beans
- Jars (Qt. sized mason or jelly jars or plastic containers)
- Rocks or marbles
- Digital balances
- Paper
- Notebooks
- Timer with alarm
- 3 Small tubs or paper bags per team
- 2 Large tubs per class

NOTE: Substitute items may easily be used. You should aim to have several different sizes of spoons, as well as 2-3 different colored beans or jar fillers.

Materials *PER STUDENT*

- *Peak Oil Game* worksheet, page 107

CONTINUED ON NEXT PAGE

Preparation

- Prepare a set of jars (two or three per group) for each student team. Glass mason or jelly jars or plastic variations of these work well. Layer or mix black beans with pinto beans, and add a few obstacles like rocks or marbles. Vary the thickness and order of the layers in the jars. If you wish, make sure that each student team has approximately the same difficulty level represented by their jars. However, this is not necessary and may not be authentic.
- Gather the other materials students will need.
- Make a copy of the worksheet for each student.
- If you wish, assign students to groups of 3-5 students each before conducting the activity.

OPTIONAL:

- Download the Peak Oil Game PowerPoint for use in explaining the procedure. The PowerPoint is available at http://www.NEED.org/oilandgasmaterials.
- Depending on the level of your students, you may choose to make nametags for the processor, driller, etc. Students can purchase extra nametags each year for their team members to demonstrate hiring additional staff to increase production.
- You may also wish to place the jars inside a shoe box or cover the jars with paper. This will make the activity more challenging, but more closely mimic the challenges faced during drilling and production of a well. Students can also buy the opportunity to do further 'exploration'.
- Depending on the number of students, it may be appropriate to designate student inspectors or assessors that monitor the other groups and their drilling sites and assess penalties.

✔ Procedure

1. Explain the game to the students, making clear the rules of the game, and the time span of each 'year'.
2. Indicate to the students which containers are to be used for processing and where clean oil should go.
3. When everyone is ready, begin the first round of play. This is year one.
4. Continue to play the game, with 30 seconds to 1 minute representing one year of production for as long as time will permit. Make sure the game is played long enough so production begins to decline.
5. Discuss with the class the obstacles each group faced and how their oil production varied as a result. Connect their difficulties to oil retrieval in the field. Also discuss how the penalties played a part in the game. How might industry professionals and assessors have to work together. How might student views towards regulations faced in the industry change after the game? Discuss the amount of waste created in the game, and make sure students understand that processing facilities can now continually reprocess the waste materials until the desired result is achieved.
6. Have each team graph their annual oil production.

Extensions

- After students have gotten a good grasp of the activity through several rounds, introduce the option to purchase a re-processing facility (bag or container) that allows students to process waste items rather than discarding them between rounds.
- Incorporate different steps beyond the three bags. For example, petroleum must often be transported between facilities. Add a step that requires beans to be transported across the table before reaching bag 2 or 3.
- Instead of trading beans for tools (using beans as currency), introduce students to the idea of selling their product (beans or oil) in the marketplace as a commodity. Appoint a few students to be consumers, and each team must take their product to "market" to sell to consumers, much like the stock market.

Activity 24: Road Trip

Background

Petroleum provides most of the energy for passenger vehicles and transportation. Gasoline and diesel fuel are both products of petroleum refining. In this activity, students will choose a vehicle, then determine the environmental impact from operating that vehicle on an extended vacation based on statistics provided by the U.S. Department of Energy.

Objective

- Students will be able to describe the impact oil and natural gas can have on the environment when used as a transportation fuel.

Time

- 1-2 class periods plus homework

Materials

- Internet access for each student
- Calculators for each student
- *Road Trip* worksheet, page 108

Preparation

- Secure computers or computer lab time so each student has internet access.
- Make a copy of the worksheet for each student.

✔ Procedure

1. Describe the activity to students and explain how much time they will have available to use computers at school. Encourage them to complete all of their internet research before doing calculations.
2. Work through a sample problem for calculating the number of gallons of gasoline consumed for a certain distance driven.
3. Have students share their trip and describe what they would change to the class or a small group. Encourage the class to ask questions of the presenters.

☑ Evaluation/Assessment

- Evaluate student knowledge gain and performance using student worksheets or science notebooks. A rubric is found on page 33.
- Answer keys for select activities can be found on pages 37-43.
- Play *Natural Gas in the Round, Petroleum Industry in the Round,* and *Oil and Natural Gas Bingo* as formative assessments throughout the unit. Instructions for these activities are found on pages 34-36.
- Evaluate the entire unit using the evaluation form on page 119 and return it to NEED.

Grading Rubric

Student Guide/Science Notebook Rubric

GRADE	SCIENTIFIC CONCEPTS	SCIENTIFIC INQUIRY	PRESENTATION
4	Student demonstrates thorough understanding of concepts through pictures, writing, and verbal communication.	Student is able to follow all steps of the scientific process: predicting, observing/recording data, and drawing a more complex conclusion related to his/her data. Student shows higher level thinking by asking his/her own questions.	Handwriting is legible. Pictures are realistic and include labels. All parts of the assignment are complete.
3	Student demonstrates understanding of concepts through pictures, writing, and/or verbal communication.	Student is able to predict, observe/record data, and draw a basic conclusion.	Handwriting is legible. Pictures are realistic and include most labels. All parts of the assignment are complete.
2	Student demonstrates a beginning understanding of concepts, may have a couple of lingering misconceptions.	Student is able to do two of the following: predict, observe/record data, draw conclusions.	Words and/or pictures may be hard to decipher at times. Pictures are present but are missing labels. The notebook has some missing components.
1	Student demonstrates confusion about concepts. Many misconceptions remain.	Student is able to do one or fewer of the following: predict, observe/record data, draw conclusions.	Words and/or pictures are hard to decipher. They may not be connected to the investigation. The notebook has many missing components.

In the Round Instructions

***Petroleum Industry in the Round* and *Natural Gas in the Round* are quick, entertaining game to reinforce information about energy sources, forms of energy, and general energy information from the *Student Informational Text*.**

Preparation

- 5 minutes

Time

- 20–30 minutes

"In the Rounds" are available on several different topics. Check out these resources for more, fun "In the Round" examples! Download each title at shop.NEED.org.

- Coal in the Round—Coal guides
- Conservation in the Round—*School Energy Experts, School Energy Managers*
- Energy in the Round—*Energy Games and Icebreakers*
- Forms of Energy in the Round—*Science of Energy* guides
- Hydrogen in the Round—*H_2 Educate*
- Solar Energy in the Round—*Energy from the Sun*
- Transportation Fuels in the Round—Transportation Guides
- Uranium in the Round—Nuclear guides

Get Ready

- Copy one set of the, *Petroleum Industry in the Round* or *Natural Gas in the Round cards*, on pages 109-111 or 112-114, on cardstock and cut into individual cards.
- Make one extra copy of the cards to serve as your answer key. These do not need to be cut into cards.
- Have copies of the *Student Informational Text* available for quick reference.

Get Set

- Distribute one card to each student. If you have cards left over, give some students two cards so that all of the cards are distributed.
- Have the students look at their bolded words at the top of the cards. Give them five minutes to review the information about their words using the *Student Informational Text*.

Go

- Choose a student to begin and give the following instructions:
    - Read the question on your card. The student with the correct answer will stand up and read the bolded answer, "I have ______."
    - That student will then read the question on his/her card, and the round will continue until the first student stands up and answers a question, signaling the end of the game.
- If there is a disagreement about the correct answer, have the students listen to the question carefully looking for key words (forms versus sources, for example) and discuss until a consensus is reached about the correct answer.
- Follow along with students using your answer key. Mark off the starting card, so you remember where you started and ended. The cards go in order vertically down each column.

Alternative Instructions

- Give each student or pair a set of cards.
- Students will put the cards in order, taping or arranging each card so that the answer is directly under the question.
- Have students connect the cards to fit in a circle or have them arrange them in a column.

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Oil and Natural Gas BINGO Instructions

Get Ready

Duplicate as many *Oil and Natural Gas Bingo* sheets (found on page 115) as needed for each person in your group. In addition, decide now if you want to give the winner of your game a prize and what the prize will be.

Get Set

Pass out one *Oil and Natural Gas Bingo* sheet to each member of the group.

Go

PART ONE: FILLING IN THE BINGO SHEETS

Give the group the following instructions to create bingo cards:

- This bingo activity is very similar to regular bingo. However, there are a few things you'll need to know to play this game. First, please take a minute to look at your bingo sheet and read the 16 statements at the top of the page. Shortly, you'll be going around the room trying to find 16 people about whom the statements are true so you can write their names in one of the 16 boxes.
- When I give you the signal, you'll get up and ask a person if a statement at the top of your bingo sheet is true for them. If the person gives what you believe is a correct response, write the person's name in the corresponding box on the lower part of the page. For example, if you ask a person question "D" and he or she gives you what you think is a correct response, then go ahead and write the person's name in box D. A correct response is important because later on, if you get bingo, that person will be asked to answer the question correctly in front of the group. If he or she can't answer the question correctly, then you lose bingo. So, if someone gives you an incorrect answer, ask someone else! Don't use your name for one of the boxes or use the same person's name twice.
- Try to fill all 16 boxes in the next 20 minutes. This will increase your chances of winning. After the 20 minutes are up, please sit down and I will begin asking players to stand up and give their names. Are there any questions? You'll now have 20 minutes. Go!
- During the next 20 minutes, move around the room to assist the players. Every five minutes or so tell the players how many minutes are remaining in the game. Give the players a warning when just a minute or two remains. When the 20 minutes are up, stop the players and ask them to be seated.

PART TWO: PLAYING BINGO

Give the class the following instructions to play the game:

- When I point to you, please stand up and in a LOUD and CLEAR voice give us your name. Now, if anyone has the name of the person I call on, put a big "X" in the box with that person's name. When you get four names in a row—across, down, or diagonally—shout "Bingo!" Then I'll ask you to come up front to verify your results.
- Let's start off with you (point to a player in the group). Please stand and give us your name. (Player gives name. Let's say the player's name was "Joe.") Okay, players, if any of you have Joe's name in one of your boxes, go ahead and put an "X" through that box.
- When the first player shouts "Bingo," ask him (or her) to come to the front of the room. Ask him to give his name. Then ask him to tell the group how his bingo run was made, e.g., down from A to M, across from E to H, and so on. group how his bingo run was made, e.g., down from A to M, across from E to H, and so on.

***Oil and Natural Gas Bingo* is a great icebreaker for a NEED workshop or conference. As a classroom activity, it also makes a great introduction to an energy unit.**

Preparation

- 5 minutes

Time

- 45 minutes

Bingos are available on several different topics. Check out these resources for more bingo options! Download each title at shop.NEED.org.

- Biomass Bingo—*Energy Stories and More*
- Change a Light Bingo—*Energy Conservation Contract*
- Coal Bingo—Coal guides
- Energy Bingo— *Energy Games and Icebreakers*
- Energy Efficiency Bingo—*School Energy Experts, School Energy Managers*
- Hydrogen Bingo—*H_2 Educate*
- Hydropower Bingo—Hydropower guides
- Nuclear Energy Bingo—Nuclear guides
- Science of Energy Bingo—*Science of Energy* guides
- Solar Bingo—Solar guides
- Transportation Bingo—Transportation guides
- Wind Energy Bingo—Wind guides

- Now you need to verify the bingo winner's results. Ask the bingo winner to call out the first person's name on his bingo run. That player then stands and the bingo winner asks him the question which he previously answered during the 20-minute session. For example, if the statement was "can name two renewable sources of energy," the player must now name two sources. If he can answer the question correctly, the bingo winner calls out the next person's name on his bingo run. However, if he does not answer the question correctly, the bingo winner does not have bingo after all and must sit down with the rest of the players. You should continue to point to players until another person yells "Bingo."

OIL AND NATURAL GAS BINGO

ANSWERS

A. Knows the main component of natural gas

B. Can name a state that is a top 5 producer of petroleum

C. Knows what percentage of oil used in the U.S. that is imported

D. Knows how natural gas is measured

E. Knows two ways to increase a car's MPG

F. Knows what percentage of U.S. electricity is generated by natural gas

G. Knows the type of rock most petroleum is found in

H. Knows two industrial products that use natural gas as a feedstock

I. Knows what percentage of total energy is supplied by petroleum

J. Used petroleum to get to the school today

K. Knows two uses of natural gas in the home

L. Knows the two types of atoms found in oil and natural gas molecules

M. Has seen crude oil

N. Knows the method refineries use to separate crude oil into useful products

O. Knows how natural gas is transported

P. Knows what OPEC stands for

A methane	**B** Texas, North Dakota, California, Alaska, North Dakota	**C** about 40%	**D** cubic feet
E proper tire inflation, regular oil change, don't keep extra weight in their car, etc.	**F** 32.2%	**G** sedimentary	**H** fertilizer, ink, glue, paint, plastic, insect repellent, synthetic rubber, man made fabrics, etc.
I 37.0%	**J** ask for description/details	**K** hot water heating, cooking, clothes dryer, fireplace	**L** hydrogen, carbon
M ask for description/details	**N** fractional distillation	**O** pipeline	**P** Organization of Petroleum Exporting Counties

Answer Key

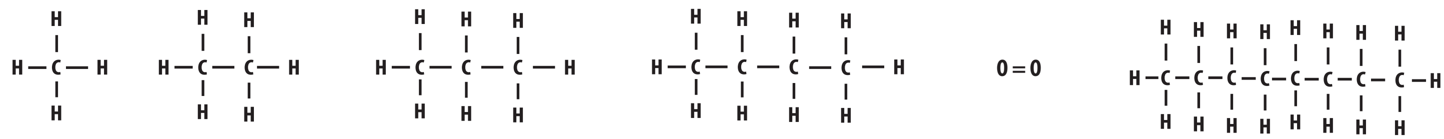
Activity 2: Chemical Models

Activity 1

- Methane—CH_4
- Ethane—C_2H_6
- Propane—C_3H_8
- Butane—C_4H_{10}
- Pentane—C_5H_{12}
- Hexane—C_6H_{14}
- Heptane—C_7H_{16}
- Octane—C_8H_{18}
- Nonane—C_9H_{20}
- Decane—$C_{10}H_{22}$

Activity 2

Methane Ethane Propane Butane Oxygen Octane



Activity 3

- Methane—$CH_4 + 2O_2 \text{--->} CO_2 + 2H_2O$
- Ethane—$2C_2H_6 + 7O_2 \text{--->} 4CO_2 + 6H_2O$
- Propane—$C_3H_8 + 5O_2 \text{--->} 3CO_2 + 5H_2O$
- Octane—$2C_8H_{18} + 25O_2 \text{--->} 16CO_2 + 18H_2O$

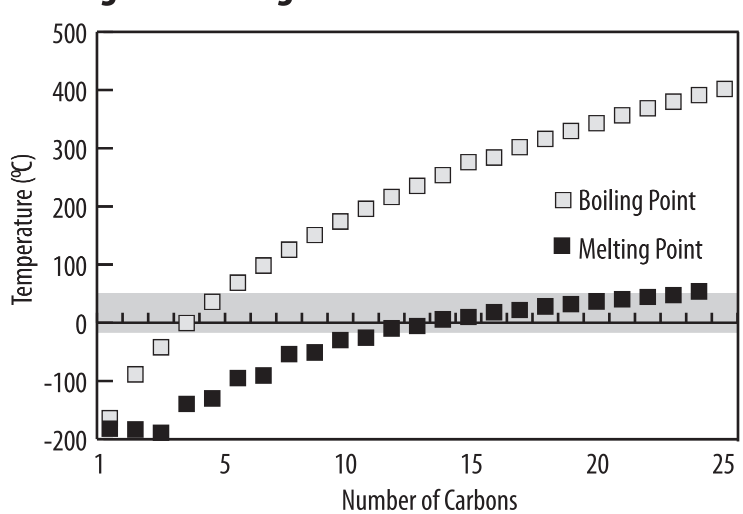
Activity 4

- Students should draw their assembled models of the equations above.

Activity 3: Hydrocarbon Properties

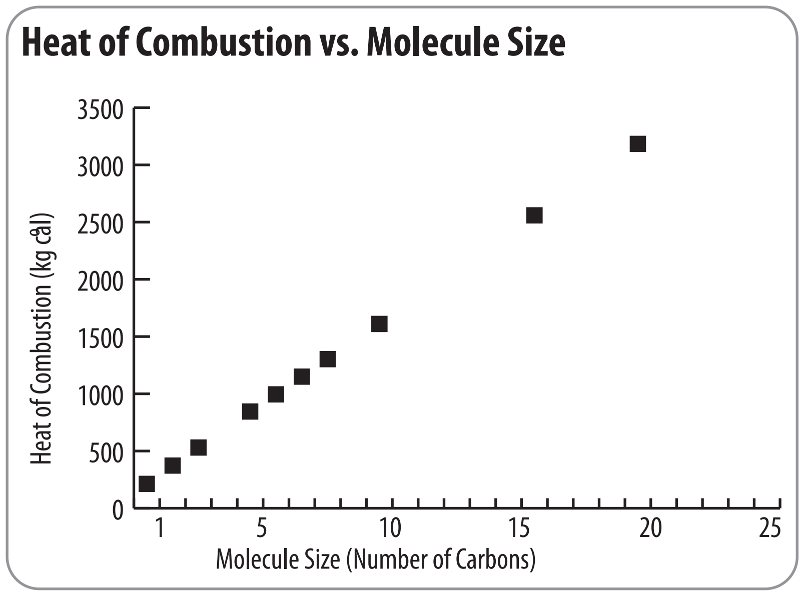
1. Where is room temperature on this graph? *Room temperature should be located around 20-23 degrees Celsius.*

Melting and Boiling Point vs. Number of Carbons



2. Explain the general trend you observe in your melting point/boiling point graph. *As the number of carbons increase, the melting and boiling points increase; the higher the number of carbons in a molecule (larger chain), the higher the amount of energy.*
3. Looking at your melting point/boiling point graph, match up the melting point and boiling point of each hydrocarbon by drawing a vertical line from the melting point to the corresponding boiling point. *Students should see 3 data sets below the shaded temperature range and 4 above the shaded temperature range.*

4. Which items do not fall in the average temperature range for melting or boiling? What state of matter do you think the items must be if their melting and boiling point are very low (under the average temperature range)? *The items with low numbers of carbons are likely to be gases, because they have such a low boiling point and have already vaporized.* What state of matter must they be if both are high (above the average temperature range)? *The items with high numbers of carbons are likely to be solids because their melting point (same as freezing point) is relatively high.* What state of matter might they be if at least one of their points falls within the average temperature range? *Liquids are items that likely fall between 4 and 20 carbons, most of which have their melting or boiling point located within the average temperature range.*
5. Why might boiling point and melting point be important for hydrocarbons? (Hint, look at the names of the items on your data table) *Answers may vary. We use hydrocarbons as transportation fuels. Students may mention that you don't want a fuel that vaporizes or freezes too easily. Students may also mention that a good transportation fuel should have a higher amount of energy to be effective for moving large items.*
6. Look at your heat of combustion graph. Heat of combustion is the amount of energy that is obtained by burning a molecule. What is the general trend you observe on this graph? *As the size of the molecule increases, so does the heat of combustion.*
7. Using your graphs and the *Fractional Distillation* graphic on page 55 of the informational text, label your heat of combustion graph to show where propane, gasoline, jet fuel, and diesel might be found within the data. Use your graphs and the graphic on page 55 to explain why these fuels might be used the way they are. *Answers may vary, but students should connect that fuels with higher heats of combustion, higher numbers of carbon, and higher amounts of energy are used as transportation fuels to move larger items—planes, ships, trains, etc.*



Activity 4: Exploring Polarity

1. Which solvent is polar? Which solvent is nonpolar? How do you know? *Water is polar and acetone is nonpolar. Polar substances dissolve polar substances and nonpolar substances dissolve nonpolar substances.*
2. Based on your observations, which peanut, A or B, is polar? How do you know? *Peanut A is polar, because it dissolved in water. Polar substances dissolve polar substances.*
3. Based on your observations, which peanut, A or B, is nonpolar? How do you know? *Peanut B is nonpolar, because it dissolved in acetone. Nonpolar substances dissolve nonpolar substances.*
4. The polar substance is *starch* and the nonpolar substance is *polystyrene foam*.
5. Gasoline is made from refined petroleum, like many hydrocarbons, and is nonpolar. What would happen if it was transported in a Styrofoam™ container? Explain why this is important. *The gasoline would dissolve the polystyrene and leak out of the container. Knowing solvents interact with their surroundings is important for safety reasons when transporting in certain containers. Some materials are dissolved by gasoline due to their polarity.*

Activity 5: Fault Blocks

1. How do the wooden blocks show what happens in the Earth's crust? *As the plates push on each other, parts of the Earth's crust are pushed upward. When they are pushed upward, the position of the different layers of sedimentary rock move up*.
2. Describe how the wooden blocks demonstrate the way mountains are formed. *Two plates pushing on each other force land upward and form mountains.*
3. Explain how the wooden blocks model the formation of a salt dome. *Plates pushing in on each other can bend a layer and create a space underneath for oil or natural gas to collect.*

Activity 6: Mapping the Ocean Floor

1. Which type of zone (convergent, divergent, or transform) does this model represent? How do you know? *Divergent, because the plates are moving away from each other.*
2. What color on your paper represents the oldest rocks? *Whichever color is farthest from the fault line.*
3. What color on your paper represents the newest rocks? *Whichever color is closest to the fault line.*
4. What color on your paper shows a time of the most movement of the plates? *Whichever color is the widest color block*.
5. What color on your paper shows a time of the least movement of the plates? *Whichever color is the narrowest color block.*
6. Where would you expect to find the oldest rocks: along the ridge in the middle where it's shallower; or at the deeper parts of the ocean? *At the deeper parts of the ocean*.
7. Would you expect to find oil and natural gas deposits beneath older or younger rocks? *Beneath older rocks.*
8. If you were employed to search for petroleum and natural gas in the ocean, what is one place in the Northern Atlantic Ocean where you would start looking? Explain your answer in at least two sentences. *Answers will vary, but should include a location in deep water, based on the oldest rocks being in the deep areas of the ocean.*

Activity 7: Exploring Sound Waves

1. Was there a difference in longitudinal waves produced from the trials at different heights? Describe. *Students' answers will vary, but should reflect their experimental results. Answers should draw on their experimental evidence.*
2. What was the difference in the two sounds you heard from the two different cups? *Students' answers will vary, but should include a reference to the pitch of the sound differing*.
3. Explain how you think seismic technology might be helpful to locate specific geologic formations underground. *Not all types of rock will reflect the sound waves in the same way or to the same degree. Geologists use the differences to construct a model of the underlying rock layers and to locate formations where oil and gas most likely will be found.*

Activity 8: Exploring Core Sampling

1. What are core samples? *Core samples are long, cylindrical sections of something, such as rock layers or a glacier, which tell scientists about the composition of the ground or glacier.*
2. Did you encounter any challenges when pulling up your core sample? If so, what was the challenge? How does this relate to real world drilling? *Students' answers will vary but should draw on their experiences and be supported by their experimental data. Challenges in the real world are encountered when a cave, large underground aquifer, or other geologic structure that cannot be sampled with a core, is encountered. Another challenge lies with the strength of the material. Very delicate, or crumbly, materials will not come out of the ground intact.*
3. What are petroleum geologists looking for when they examine core samples? *Geologists are looking for formations of specific rock types that are porous, or salt domes that are likely to contain oil or gas.*
4. What about your core sample might be similar or different from an actual core sample? *Student answers will vary.*

Activity 9: Exploring Porosity

1. Which size of gravel has the greatest porosity? Explain why. *The largest material used in the activity will have the greatest porosity. This is because there are more spaces between the rocks, beads, or other objects that were used to contain the water.*
2. Explain porosity's importance in determining the best location for an oil well. *Porosity helps determine how well a substance will hold oil or gas.*

Activity 10: Getting the Oil Out

1. Which length of straw required the most effort to bring the liquid to the top? Which length of straw required the least effort to bring the liquid to the top? Explain why. *The longest length of straw requires the greatest effort. The shortest length of straw requires the least effort. This is because the force to remove the oil must be applied over a greater distance, which requires more power.*

Activity 11: Perforated Well Casing

1. How did perforating (poking holes in) the straw change the amount of water your collected? *More water should have been produced when the straw was perforated, as opposed to when it was not punctured.*
2. Using your observations, explain how perforating a well casing would be beneficial in a drilling scenario? *Perforating the well casing allows the oil or gas to flow freely into the well casing from more than one opening.*
3. How could you improve this model? *Student answers will vary.*

Activity 12: Visualizing Hydraulic Fracturing

1. Describe the movement of the fluid and why it moved the way it did. *Student results will vary based on set-up and execution; however, the syrup should push and spread out into the open spaces between the gel beads.*
2. Did you notice any movement in the beads? If so, describe and explain why this might have occurred. *Answers will vary. The beads should wiggle closest to the straw and the spaces between the beads in this area should become a bit larger or more visible.*
3. Explain how this activity models concepts of hydraulic fracturing. *Answers will vary, but should relate the syrup to the fracturing fluid, and how it, when injected under pressure, causes larger openings or fractures to appear. The fluid will then spread out into those open pores. This is how we can remove the gas trapped within the pores of rocks like shale.*
4. No model is perfect – all models have limitations. Describe the limitations of this model. How could you improve this model? *Student answers will vary. They may suggest that the beads, the fluid, or the injection method are not exactly correct. Good answers should explain why the model is inaccurate and provide a suggestion or solution for improving the model.*

Activity 13: Fracturing With Gelatin

1. What happened with the syrup and gelatin in this system? Why did they behave this way? *The syrup should drain out of the hole in the straw, but some will remain in the fractures, holding them open. The fractures are created because the liquid cannot be compressed when injected into the gelatin and it pushes the jello apart, or fractures it.*
2. How does the syrup simulate a fracturing fluid in the process of hydraulic fracturing? *Students should make the connection that - like the syrup -* fracturing *fluid will push the porous rock apart and create openings. The syrup is thick and sticks in the cracks to some extent, whereas the* fracturing *fluid is a mixture of sand, water, etc. The sand will hold the fractures open when the water drains out. This set-up allows the oil and gas to flow and be pumped out.*
3. How could you improve this model? *Student answers will vary.*

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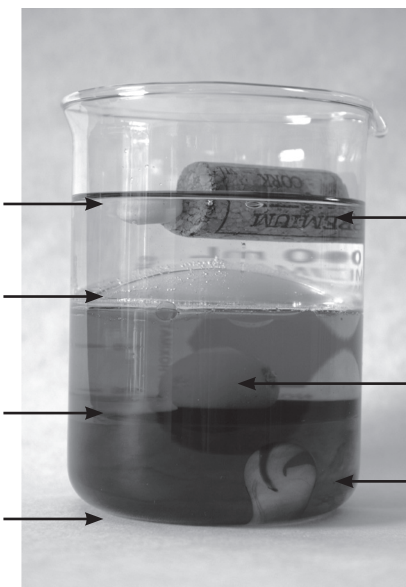
Activity 14: Fracturing a Cake

1. What happened to the Magic Shell® when it was injected into the cake? *The chocolate seeped into and then spread out into the "pores" of the cake. It then hardened into that space.*
2. What would happen to the Magic Shell® if the cake was more or less porous? *If the cake was less porous, the chocolate wouldn't expand as much is it did into the cake and the cake would just crumble. If the cake was more porous, however, the chocolate would just ooze and form a pool.*
3. Did the Magic Shell® travel through the icing that separated the layers? Why do you think it behaved this way? *Students should have seen that the icing stayed between the layers, due to the density, porosity, and permeability difference of the icing.*
4. What might the icing represent when using hydraulic fracturing to recover oil and natural gas? Explain. *Icing can represent different layers of rock above and below the shale formation that are impermeable.*

Activity 15: Understanding Density

1. What did you learn about the densities of liquids? *Lower density liquids will rise above higher density liquids.*
2. What did you learn about the densities of objects? *The density of an object will determine whether it will sink or float. Objects higher in density than the liquid will sink in the liquid. Objects lower in density than the liquid will float in the liquid.*

Extension answers: *Densities: Oil: 0.881 g/cm^3 Aluminum: 2.70 g/cm^3 Copper: 8.93 g/cm^3 Nickel: 8.90 g/cm^3*



Activity 16: Using Density to Extract Petroleum

1. How can you relate each part of the experimental set-up to the process of getting petroleum out of the ground? Explain each step. *Students' answers will vary, but should relate the flask to the oil-containing rocks underground, the tubing to the well, and the vegetable oil to the petroleum.*
2. How could density be used as a way to force oil out of a well with slowed production? *Water can be pumped into the well to flood it and float oil to the top to be pumped out.*

Activity 17: Polymers

Part One

1. Is this polymer a liquid or a solid? Explain your answer. *The polymer is like a liquid because it will flow, and will allow an object to sink inside it when gentle pressure is applied. The polymer is like a solid because when it is struck sharply, nothing can get inside.*

Part Two

1. What happened when you combined the glue solution and the borax solution? *Students' answers will vary somewhat, but should include a good description of their observations during the experiment.*
2. Explain how this is a polymer. *The borax links the glue molecules together to form a much larger molecule of repeating glue molecule units.*

Activity 19: The Natural Gas Chain

This is one possible way to complete the chart:

Center: Production

Additional Steps and Effects

Exploration
A new natural gas field is discovered, increasing the available supply for production.
More natural gas is needed to be produced, exploration of new areas increases.

Liquefaction
A new liquefaction plant opens, natural gas production can increase.
Excess natural gas is being produced, a liquefaction plant adds another shift to its schedule.

Storage
A very cold winter causes LNG storage to be low, natural gas production increases to fill storage capacity.
Natural gas production doesn't meet demand, LNG is used from storage.

Transportation
A new company produces more LNG ships, allowing natural gas production to increase.
Natural gas production slows, less transportation is needed.

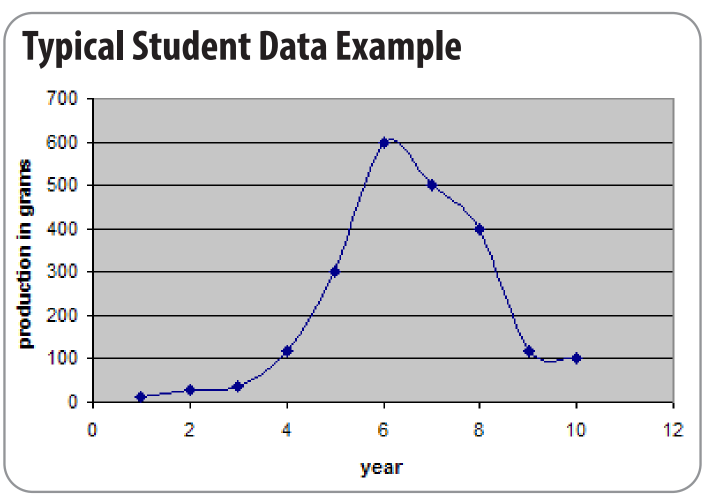
Regasification
A regasification plant needs maintenance, natural gas production decreases.
Less natural gas is being produced, a plant increases the LNG being regasified.

Distribution
A major pipeline needs repair, natural gas production decreases.
Natural gas production increases and new pipelines are built to transport it to new locations.

End Use
Consumer demand for natural gas is high, production increases.
Production increases, but demand is low, consumer prices decrease.

Activity 23: Peak Oil Game

1. *An example of student data might look like this. Their peak may shift slightly depending on their use of tools and extra labor.*



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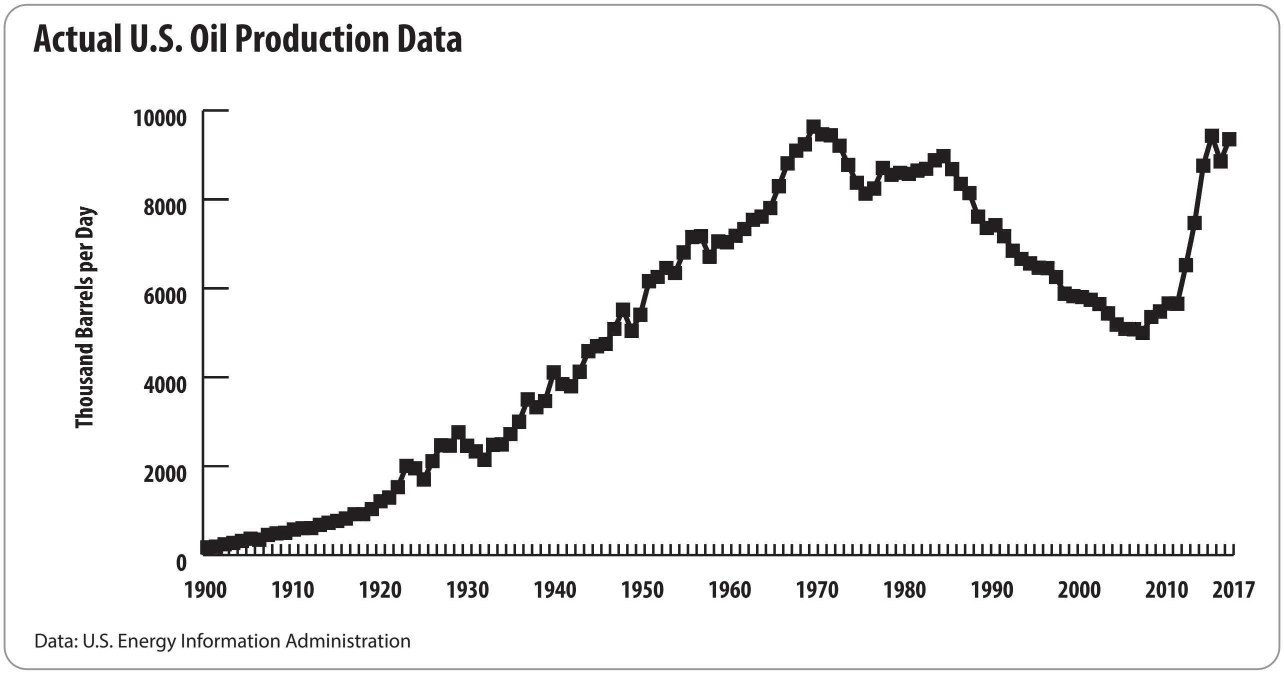
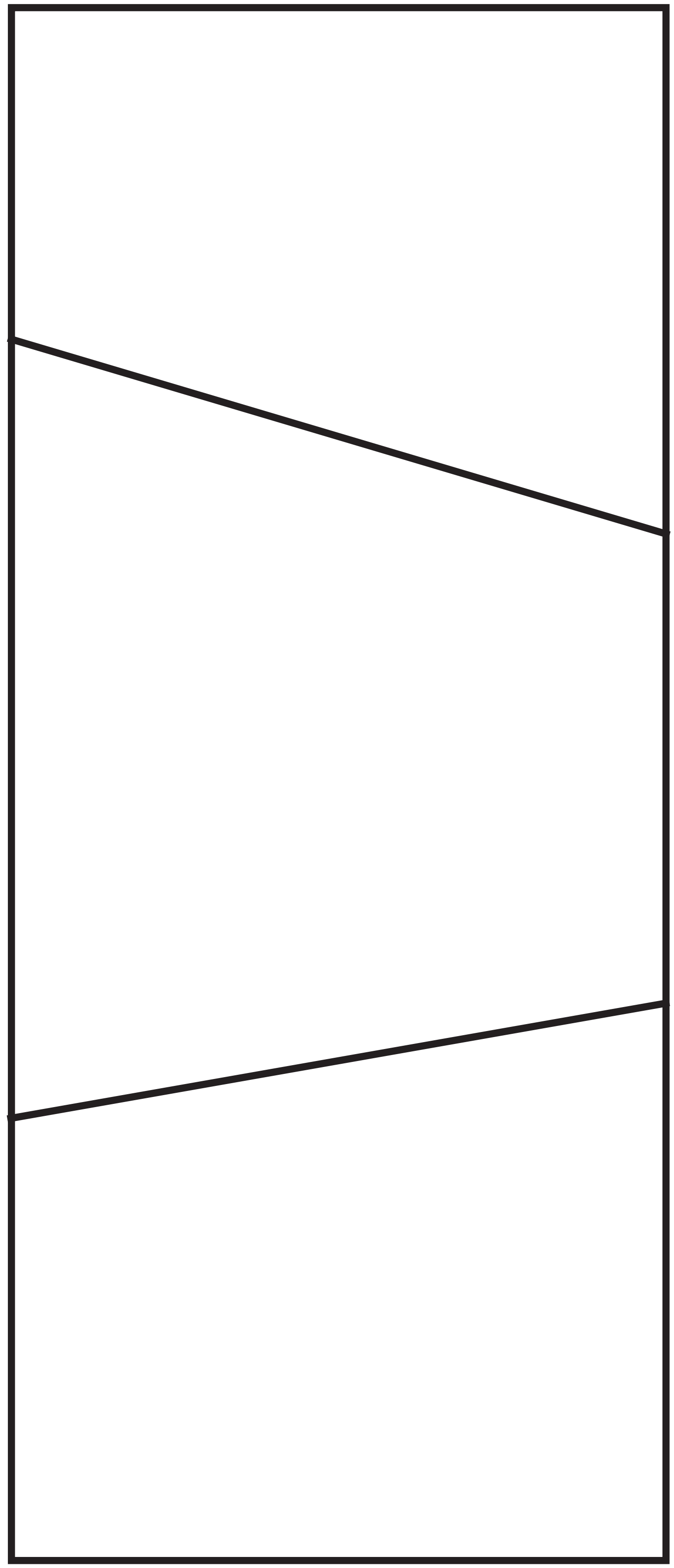
How does your graph compare to the real oil production graphs for the U.S. and world oil production? *Answers will vary, refer to graph below.*



2. Did the oil in your oil field really run out? *Answers may vary, but most students should have had some oil remaining that was difficult to retrieve.*
3. Estimate the percent of the original oil left in your oil field. *Answers will vary for each group.*
4. How is this model similar to the real world? *Students should be able to make connections describing the initial ease of drilling for oil, the challenges faced when demand is present, how tools, technology, and increased power can enhance results, environmental and economic costs, etc.*
5. How is this model different from the real world? *Students may take a more literal response citing the physical differences in the model and the real world. Encourage students to think outside of the box or jar to identify more significant and relatable differences, such as the emptying of their processing plant between rounds.*
6. Why might companies stop purchasing technology to produce oil from a well, or choose to abandon it? *The economical or physical demands may outweigh the financial gains.*

Fault Blocks



Student Informational Text

Introduction to Petroleum and Natural Gas

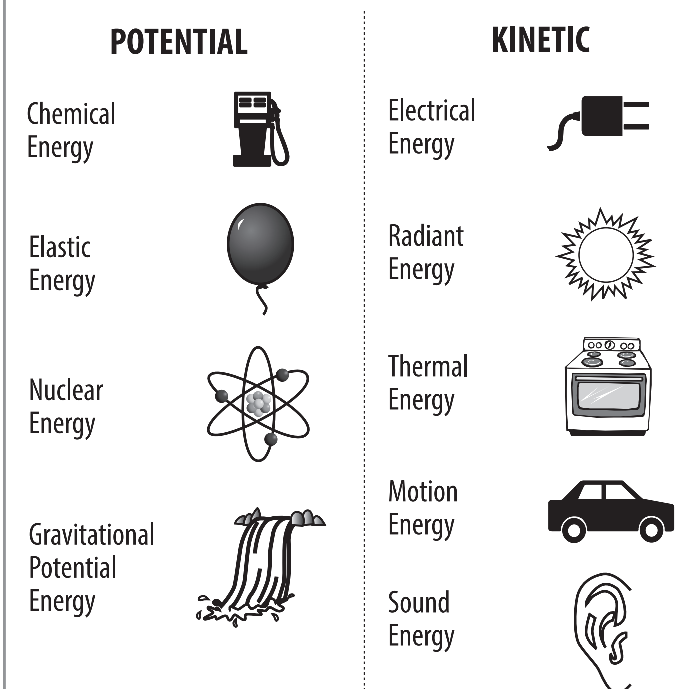
Petroleum and **natural gas** impact our lives in many ways every day. Together, they supply more than sixty percent of our nation's energy. Petroleum provides most of the fuel for our sources of transportation – gasoline, jet fuel, and diesel fuel are all made from **crude oil**. Natural gas heats most homes in the U.S. and provides energy for hot water and cooking for a significant number of families. Some older homes burn fuel oil for heat, which is a product obtained from petroleum. Many electric power plants throughout the country are fueled by natural gas because it is efficient, clean burning, and can be instantly ignited when electrical demand is high. Some areas, and Hawaii in particular, use petroleum to provide electricity.

Petroleum and natural gas aren't just burned for energy. They are also used to manufacture many products such as soft drink bottles, dent-resistant car fenders, medicines, and sporting equipment like skateboard wheels and protective helmets and pads. You probably are unaware of all the ways you encounter petroleum-based products every day.

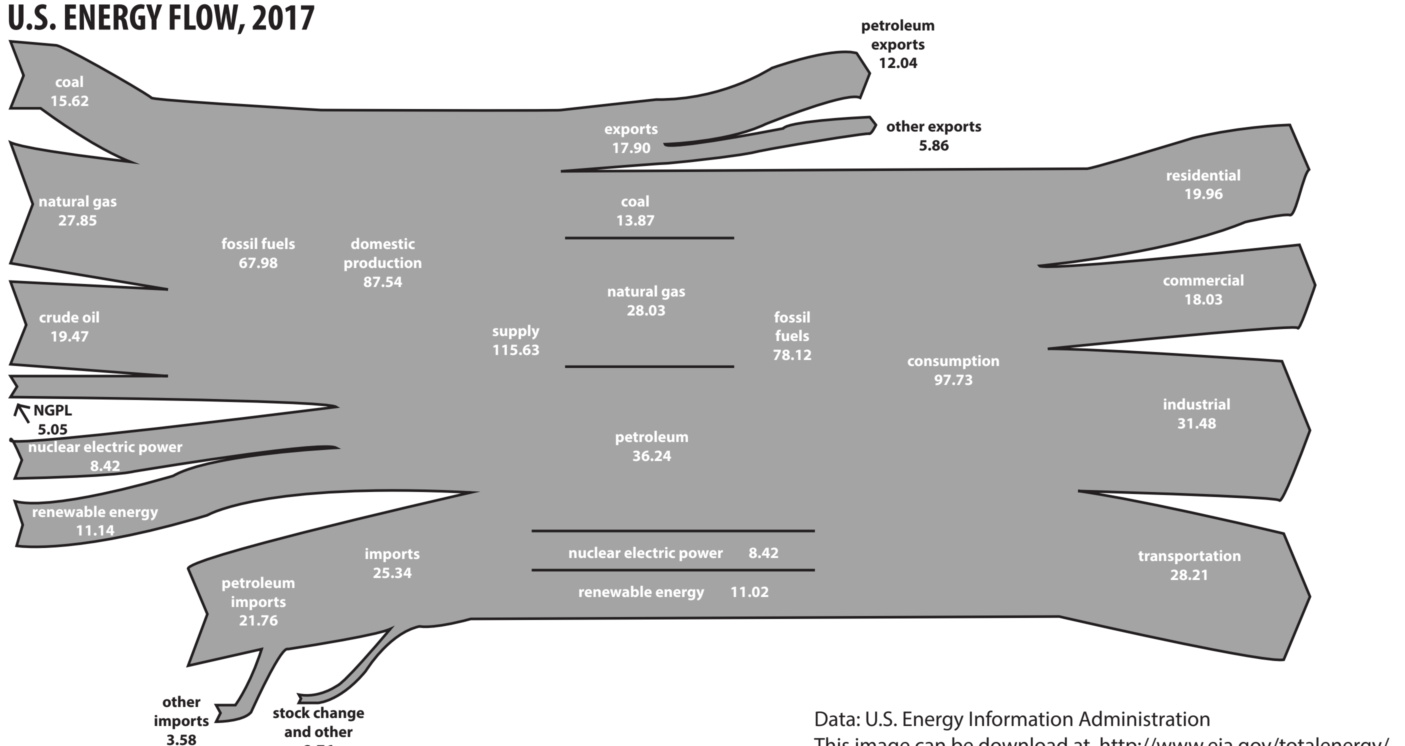
What is Energy?

Energy causes change; it makes it possible to do everything every day. Energy heats our homes, propels our transportation, powers our computers and other electronics, and makes it possible for our bodies to function properly. Scientists define energy as the ability to do work.

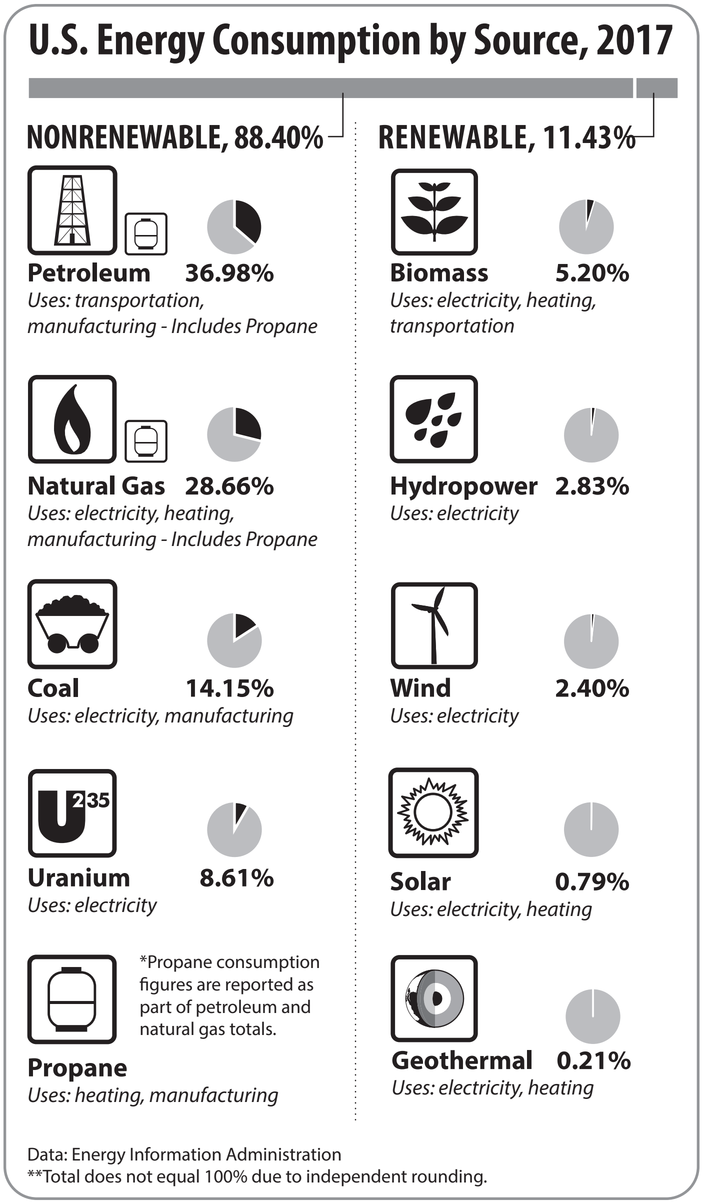
Forms of Energy



U.S. ENERGY FLOW, 2017



Data: U.S. Energy Information Administration
This image can be download at http://www.eia.gov/totalenergy/



Forms of Energy

Energy exists in two major forms: potential and kinetic. All forms of energy with which you are familiar, such as light, sound, and electricity, can be classified as one of these two forms.

Potential energy is stored energy. We store energy in a variety of ways. Batteries contain chemicals that can transform into electrical energy when connected to a device such as a flashlight or toy. Most of the potential energy that we use is chemical energy, but potential energy includes gravitational potential energy, or energy of position, nuclear energy, and elastic energy. If you have ever pulled back on a rubber band, you have stored some elastic energy in that rubber band.

Kinetic energy is the energy of motion. Because light, sound, electricity, and thermal energy are all in motion, they are classified as kinetic energy.

Energy can be transformed, or changed, from one form to another. Batteries change chemical energy into electrical energy. Moving air, or wind, can change motion energy into electrical energy with a wind turbine. Toy cars that are pulled back and let go are transforming elastic energy into motion.

Sources of Energy

People have always used energy to do work for them. Thousands of years ago, early humans burned wood to provide light, heat their living spaces, and cook their food. Later, people used the wind to move their boats from place to place. More than 135 years ago, people began using falling water to make electricity.

Today, people use more energy than ever from a variety of sources for a multitude of tasks and our lives are undoubtedly better for it. Our homes are comfortable and full of useful and entertaining electrical devices. We communicate instantaneously in many ways. We live longer, healthier lives. We travel the world, or at least see it on television and the internet.

The ten major energy sources we use today are classified into two broad groups—nonrenewable and renewable. **Nonrenewable energy sources** include coal, petroleum, natural gas, propane, and uranium. They are used to generate electricity, to heat our homes, to move our cars, and to manufacture products from candy bars to personal tablets. These energy sources are called nonrenewable because they cannot be replenished in a short period of time. The processes that created nonrenewable resources like petroleum are hundreds of millions of years in the making.

Renewable energy sources include biomass, geothermal, hydropower, solar, and wind. They are called renewable energy sources because their supplies are replenished in a short time. We use renewable energy sources mainly to make electricity. Is electricity a renewable or nonrenewable source of energy? The answer is neither. Electricity is different from the other energy sources because it is a **secondary source of energy**. That means we have to use another energy source to make it.

Formation of Petroleum and Natural Gas

Petroleum and natural gas are **fossil fuels**. Petroleum is often called crude oil. Petroleum and natural gas are considered fossil fuels because they were formed from the remains of tiny sea plants and animals that died hundreds of millions of years ago before dinosaurs lived. When the plants and animals died, they sank to the bottom of the oceans.

Over time, the plant and animal remains were buried by thousands of feet of sand and sediment, which turned into **sedimentary rock**. As the layers increased in depth, they pressed harder and harder on the decayed remains at the bottom. The heat and pressure eventually changed the remains into petroleum or natural gas. Both are classified as a nonrenewable energy source because they take hundreds of millions of years to form. We cannot make new petroleum reserves or natural gas deposits in a short period of time. Natural gas from underground reservoirs is considered a nonrenewable energy source, but there are some renewable sources of methane, such as landfills.

Not all organic material buried underground turns into petroleum or natural gas. Certain geological conditions must exist within the rock formations for the transformations to occur. First, there must be a trap of **non-porous** rock that prevents the material from seeping out, and a seal (such as salt or clay) or cap rock to keep the material from rising to the surface. Even under these conditions, only about two percent of the organic material is transformed into petroleum.

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When Did Natural Gas and Petroleum Form?

Even though both petroleum and natural gas come from ancient plant and animal matter, in geologic time, they are young. Most petroleum comes from rocks that are about 300-400 million years old. Natural gas is found in similarly aged rock. Scientists believe the Earth is over four billion years old, with life existing on Earth for about 3.7 billion years. Dinosaurs first roamed the Earth about 248 million years ago.

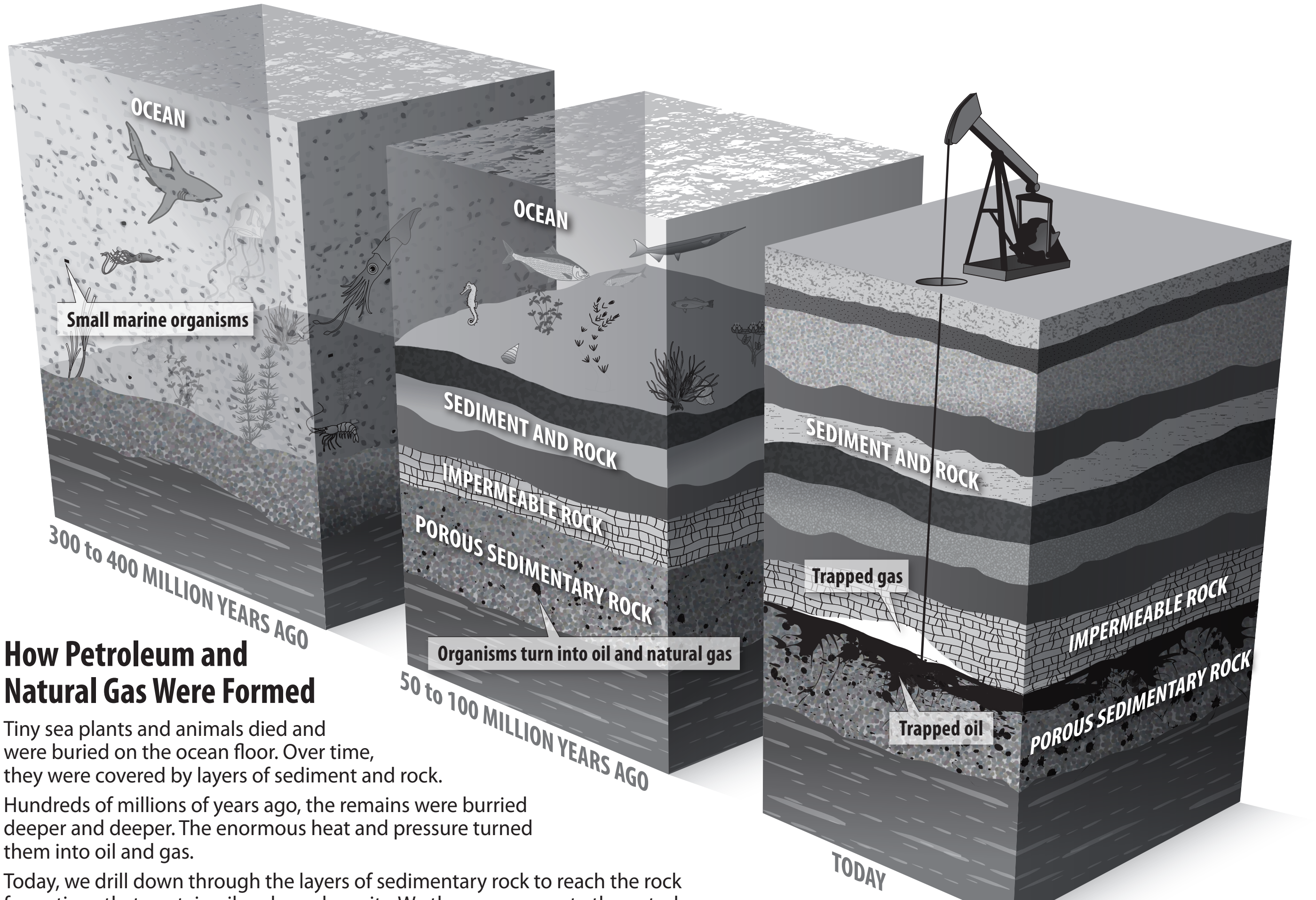
Petroleum deposits are locked in **porous** rocks like water trapped in a wet sponge. A typical reservoir is mostly sandstone or limestone in which petroleum is trapped. Petroleum can be various colors - almost clear or dark black, and just out of the ground is called crude oil. The characteristics of crude oil vary in different locations. Some crude is very clear and moves like water. This is usually called light crude. Other crude is very dark and thick like tar and almost a solid at normal temperatures.

Petroleum and Natural Gas History

People have used naturally available crude oil for thousands of years. The ancient Chinese and Egyptians, for example, burned petroleum to produce light. The ancient peoples of Greece, Persia, and India discovered natural gas many centuries ago. The people were mystified by the burning springs created when natural gas seeping from cracks in the ground was ignited by lightning. They sometimes built temples around these eternal flames so they could worship the mysterious fire. About 2,500 years ago, the Chinese recognized that natural gas could be put to work. The Chinese piped the gas from shallow wells and burned it under large pans to evaporate seawater for the salt.

Before the 1850s, Americans often used whale oil for light. When whale oil became scarce due to overfishing, people began looking for other oil sources. In some places, petroleum seeped naturally to the surface of ponds and streams. It was skimmed and burned in place of whale oil.

Kerosene, found in petroleum, was commonly used to light America's homes before the arrival of the electric light bulb. As demand for kerosene grew, a group of businessmen hired Edwin Drake to drill for petroleum in Titusville, PA. After much hard work and slow progress, he discovered petroleum in 1859. Drake's well was only 69.5 feet deep, very shallow compared to today's wells. Drake refined the petroleum from his well into kerosene for lighting. Gasoline and other products made during refining were simply thrown away because people had no use for them. In the late 1800s, the development of the horseless carriage, or automobile, with its internal combustion engine, stopped the waste of such energy-rich resources. As the demand for the automobile grew, so did the demand for gasoline. By 1920, there were nine million motor vehicles in this country and gas stations were opening everywhere.



How Petroleum and Natural Gas Were Formed

Tiny sea plants and animals died and were buried on the ocean floor. Over time, they were covered by layers of sediment and rock.

Hundreds of millions of years ago, the remains were burried deeper and deeper. The enormous heat and pressure turned them into oil and gas.

Today, we drill down through the layers of sedimentary rock to reach the rock formations that contain oil and gas deposits. We then can separate the petroleum, natural gas, and propane for use.

Note: not to scale

Natural gas was first used in America in 1816 to illuminate the streets of Baltimore with gas lamps. Lamplighters walked the streets at dusk to light the lamps. Soon after, in 1821, William Hart dug the first successful American natural gas well in Fredonia, NY. His well was 27 feet deep, quite shallow compared to today's wells. The Fredonia Gas Light Company opened its doors in 1858 as the nation's first natural gas company. By 1900, natural gas had been discovered in 17 states. In the past 40 years, the use of natural gas has grown. Today, natural gas accounts for 28.66 percent of the energy we use, and is our number one source for electricity generation.

Composition of Petroleum and Natural Gas

Like all living things, petroleum and natural gas are a mixture made of several carbon compounds including **aromatics** and **olefins**, and are excellent sources of energy. Petroleum and natural gas are also made of hydrogen, and are referred to as **hydrocarbons**. Because the living things that turned into petroleum and natural gas did not have the opportunity to complete the decay process, there is a great deal of chemical energy stored in their molecular bonds.

Petroleum, or crude oil, is a mixture of many different compounds, and the composition of petroleum can vary greatly from place to place. Petroleum is not just dark brown or black; it is also found in yellowish, reddish, and even greenish tones. Sometimes it is very thick and sticky, and sometimes it is runny. The thickness, or resistance of a liquid to flow, is known as **viscosity**. The higher the viscosity, the thicker the liquid.

Petroleum is categorized according to its color, viscosity, and sulfur content. These **physical properties** of the crude oil help determine how it will be used. For example, West Texas Intermediate (WTI) is categorized as "sweet," with a very low sulfur content and very low viscosity. The physical properties of WTI make it very suitable for refining into gasoline. "Sour" crude oils are heavier and more viscous, have a higher sulfur content, and are more expensive to refine than sweet crude oil.

Table 1

Heats of combustion of some hydrocarbons found in petroleum and natural gas, and other energy sources.

Compound	Chemical Composition	Heat of Combustion (BTU/lb.)
Methane	CH_4	23,900
Ethane	C_2H_6	22,400
Propane	C_3H_8	21,700
Gasoline	5-10 Carbon atoms	20,400
Paraffin	70 or more carbon atoms	19,900
Kerosene	10-16 carbon atoms	19,862
Diesel Fuel	14-20 carbon atoms	19,300
Coal (Anthracite)		14,000
Coal (Lignite)		8,000
Wood		6,500

Petroleum and Natural Gas Timeline

Petroleum

- Ancient Chinese and Egyptians burned oil for light
- 3000-2000 BCE: Bronze Age
- 625 BCE-476 AD: Roman Empire
- 1497: Foundation of British Empire
- 1783: United States of America wins Independence from Great Britain
- 1850: Whale oil became hard to find and a substitute was needed
- 1859 Edwin Drake struck oil and natural gas in Titusville, PA. This marked the beginning of the oil industry
- 1880: Industrial Revolution
- 1892 Development of automobile created use of previously discarded gasoline
- 1913 Henry Ford builds first moving assembly line
- 1920: 9,000,000 vehicles in the U.S. increased the demand for gasoline
- 1935 Nylon is invented. Nylon is an important product made from petroleum
- 1960 OPEC (Organization of Petroleum Exporting Countries) was founded
- 1967 First production of oil at the Alberta Tar Sands in Canada
- 1975 Strategic Petroleum Reserves were set up in response to the 1973 oil shortage
- 1977 Trans-Alaska oil pipeline is completed
- 2017: Petroleum supplies 36.98% of our total energy needs

Timeline: 3000-2000 BCE | 625 BCE-476 AD | 1497 | 1783 | 1810 | 1820 | 1850 | 1860 | 1880 | 1890 | 1900 | 1910 | 1920 | 1930 | 1940 | 1950 | 1960 | 1970 | 1980 | 2017

Natural Gas

- Ancient Greeks, Persians, Indians burned seeping gas from cracks
- Approx 400 BCE Chinese piped gas from shallow wells and burned it to evaporate sea water for salt
- 1816 Baltimore streets had gas lamps
- 1820 William Hart drills the first successful gas well in Fredonia, NY, creating the Fredonia Gas Light Company
- 1859 Edwin Drake struck oil and natural gas in Titusville, PA. This marked the beginning of the natural gas industry
- 1885 Robert Bunsen invented the Bunsen burner
- 1891 A 120-mile-long pipeline was built to transport natural gas from central Indiana to Chicago, but it was not very efficient
- 1925 The first all-welded natural gas pipeline was built. It was 200 miles long and stretched from Louisiana to Texas
- 1959 The Methane Pioneer transported liquefied natural gas from Louisiana to the United Kingdom
- Natural gas supplies nearly 28.66% of the energy we use

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The composition of natural gas deposits from location to location does not vary as much as petroleum. Natural gas is typically a mixture of mostly **methane**, along with some ethane, propane, and butane. Natural gas is colorless and odorless. Gas utilities often add a chemical, called **mercaptan**, to the gas to give it a distinctive odor. This allows people to quickly and easily identify the presence of natural gas and to tell if a gas line or appliance is leaking.

The **chemical properties** of the compounds in petroleum and natural gas products determine how they are used. The **heat of combustion** of a compound tells how much energy could be transformed when burning the compound. Table 1 on the previous page shows the heats of combustion for some important compounds found in petroleum and natural gas as well as wood and coal, other items burned for energy.

Note that the amount of energy contained in a pound of gasoline is more than three times the amount contained in a pound of wood. The amount of energy stored in petroleum and natural gas makes them excellent choices for transportation fuels.

In general, the density of a hydrocarbon increases as the molecules increase in number of carbon atoms. Because they are more closely packed together, larger-molecule hydrocarbons like kerosene and diesel fuel are typically used in high-power applications such as passenger jets and semi-tractors. However, as the size of the molecule increases, the cleanliness of the fuel decreases. One important challenge in using larger hydrocarbons is that they emit more air pollution than the smaller molecules when burned.

Exploration Technologies

Because oil and gas are underground, finding them requires special techniques and equipment. There are several ways oil and gas can be located.

▪ Seismic Technology

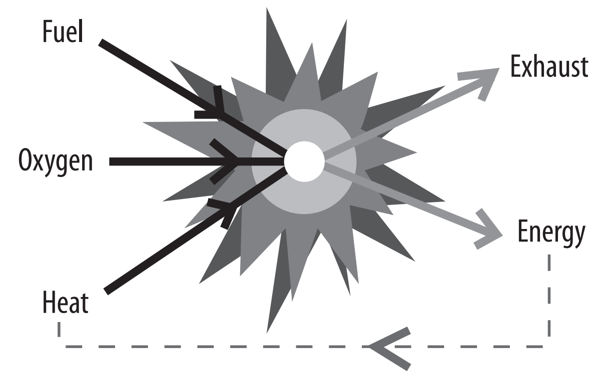
Seismic technology uses seismic waves to reveal what lies deep in the ground. Seismic waves can travel through some materials more easily than others. When these waves are directed into the ground and hit something they cannot penetrate, they bounce back, returning to the surface. Equipment on the surface records the returning waves. Once the waves have all been recorded for an area, the information is taken back to a lab where geoscientists analyze the data. A map of the underground terrain can then be created.

On land, vibrations or acoustic pulses (sound waves) are set off by small explosive charges in the ground or by thumper trucks. These special trucks have a hydraulic pad that is set on the ground underneath the truck to shake the ground with tremendous force at a rate of 5 to 80 times per second. The vibrations are audible and penetrate deep into the **strata**. The vibrations are reflected back to the surface and are detected by **geophones**.

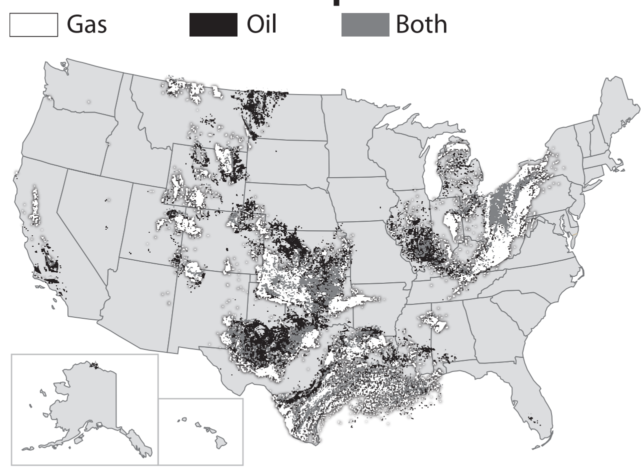
▪ 3-D Imaging

To create a 3-D image of the layers of ground, sophisticated seismic instruments are used. Numerous probes are placed in holes around a site. Each of these instruments records wave data, which is fed into a computer and used to build extensive 3-D models of underground rock formations. Then scientists can combine all of these images to get a better understanding of what lies underground. Today, seismic data is interpreted in high tech ways. Visualization in 3-D puts seismic information into a three-dimensional format that people can more easily understand. One of the most advanced 3-D visualization projects is known as the **CAVE** (Cave Automatic Virtual Environment). The CAVE is an entire room used for visualization. In this virtual reality environment, the walls and floor are used as projection surfaces, giving the appearance of filling the room and allowing scientists to walk into the data.

Combustion



Oil and Natural Gas Exploration



Data: Energy Information Administration

THE CAVE 3D SEISMIC VISUALIZATION ROOM

▪ Underwater Exploration

When searching for petroleum under the sea floor, seismic equipment must be adapted for the marine environment. Boats carrying tow cables attached to sound devices called **hydrophones** send down vibrations. These vibrations are set off by releasing bubbles of compressed air, which send out sound waves as they contract and expand while rising to the surface.

▪ Gravity Exploration

Rock layers of varying densities have different masses, and therefore slightly different gravitational pulls. **Gravimeters** can measure these differences at the surface using a weight suspended from springs. The detectable differences are as tiny as one part in ten million. Variations in density reveal certain **subterranean** features such as salt domes and masses of dense rock that allow geologists to visualize the subsurface rock structure.

▪ Magnetic Exploration

Searches are conducted from an aircraft equipped with a device called a **magnetometer**. It detects differences in the magnetic fields of the rock layers. Sedimentary rocks, where petroleum and gas are usually found, are less magnetic than **volcanic rocks**.

Retrieving Petroleum

▪ Permitting and Leasing Land

Once a site has the potential for petroleum extraction, companies must get permission to drill. In some areas, this means acquiring the needed permits from state government and leases from landowners to drill on private land. In other cases, it is federal land and requires leases and permits from the U.S. Bureau of Land Management (for onshore drilling) or the Bureau of Ocean Energy Management and the Bureau of Safety and Environmental Enforcement (for offshore drilling). There are also environmental protection measures that must be in place before drilling can begin.

Geology Rocks!

▪ Rock Formation

The field of **stratigraphy** is the study of rock layers (or strata) to determine the type of rock formation, the age of the layers, the radioactivity of the formations, and other information to determine the composition, origin, and location of rock strata.

Compiling information on rock formations is an important part of oil and gas exploration. Different types of rock have varying potential for holding oil or gas in a reservoir. There are three different types of rock: sedimentary, metamorphic, and igneous. Every rock fits into one of these three categories.

Igneous rock is formed from hardened magma or lava, liquid rock, that exists in the Earth's core or seeps to the surface through cracks in the Earth's crust. Igneous rock is usually the most dense of the three rock types. Igneous rock can have very few to many pores, depending on the rate at which it hardened.

Sedimentary rock is formed by the build-up of layers of sand and sediment over time. These layers are created as materials on the Earth's surface are eroded, washed downstream, and deposited on shores or the bottom of waterways. Over thousands of years, these particles are compressed to create rock. Most oil is found in sedimentary rock because these rocks formed in the presence of ancient plant and animal life. Since sedimentary rock often has many pores, it is an ideal formation to contain oil and natural gas.

Metamorphic rock began as either sedimentary or igneous rock. It was exposed to increased pressure and heat and eventually changed into metamorphic rock. Frequently, metamorphic rock is found near other types of rock. It is also usually more dense than sedimentary rock because the pores were removed by heat and pressure.

▪ Porosity and Permeability

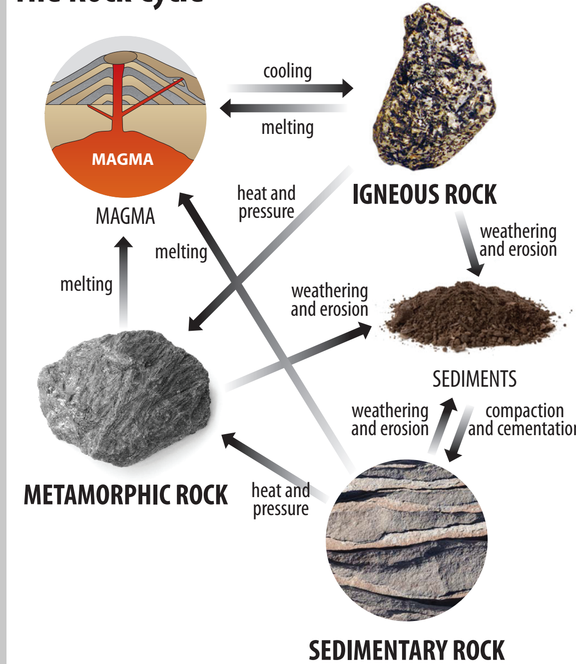
Oil and natural gas occur naturally in the Earth's layers, inside of rocks. Rocks are not completely solid; they have tiny holes, or **pores**, in which air or other fluids were trapped during formation. The **porosity** of a rock formation is a measure of the number and kind of pores it has. Pores can be various sizes and shapes and vary based on the rock's formation and changes over time.

Fluids can move between rock pores in varying degrees. **Permeability** is a measure of the ability of a rock to allow for fluid movement through its pores. Permeability is a very important feature for finding oil and gas. Being successful at finding oil is partially determined by locating porous rock, as well as locating other fluids, such as water, that are contained in rock formations. Geologists must look for rock that has good porosity but also has high permeability for easily recoverable resources.

▪ Geologic History

An important factor in finding oil and gas is understanding the environment that existed in an area millions of years ago. Since oil and natural gas are the remains of ancient sea life, the first step in locating oil is finding areas where ancient seas once existed.

The Rock Cycle



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▪ Drilling

Since the first petroleum well was drilled in 1859 by Edwin Drake, petroleum production has become an increasingly complex and precise process. The original methods of drilling for petroleum were based on ancient methods for finding water and salt. As wells have gotten deeper and more complex, drilling technology has also become more complex.

To drill a well, a large drilling rig, often called a **derrick**, is brought to the site. Once it is staged above the desired location, drilling can begin. **Roustabouts** work on the rig and handle many of the different elements of drilling.

Drill bits have sharp teeth that rotate to tear apart rock while the well is drilled. As the well gets deeper, lengths of 30-foot pipe are attached to the top of the drill. Each 30-foot section must be lifted above the last section and screwed onto the previous section. This is one of the reasons drilling platforms are very tall.

When drilling a petroleum well, the rock that is torn by the drill bit (called debris) does not come easily to the Earth's surface. As the hole gets deeper, debris can get in the way, blocking the hole. For this reason, drillers use mud to lift debris out of the well. Drilling **mud** originally was actual mud found on the drill site. Today, mud is a complex material specifically made for its drilling. Because it is so complex, mud is one of the biggest expenses in drilling.

Mud flow is controlled by the mud engineer. It is pumped down the hollow drilling pipe. It comes out near the drill bit, cooling the bit. The mud then carries debris up through the well as it is pumped, to be collected above ground. One of the reasons mud is so expensive is that it must be formulated with precise **density**. Since less dense materials float on top of more dense materials, the mud must have a greater density than the rock being cut. Drilling mud also keeps the formation, or walls of the well, from collapsing inward.

Once a well has been drilled to the depth of the petroleum reservoir, the workers move into the next stages—well completion and production. The drilling rig is removed from the site and the well is prepared to begin producing crude oil.

DRILL BIT

OIL DERRICK

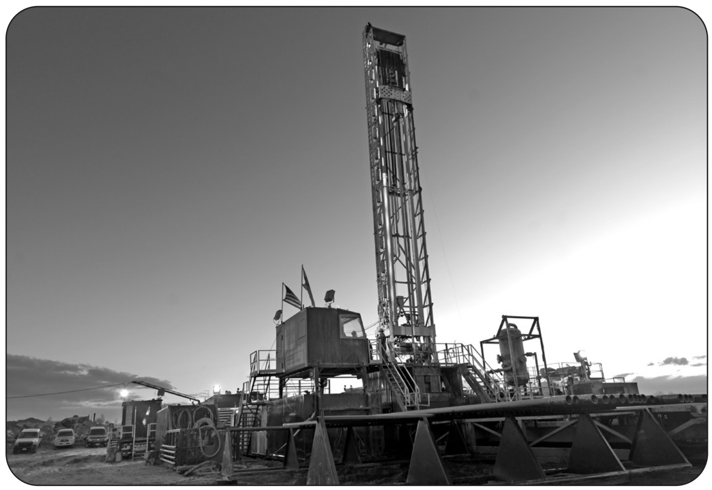


IMAGE COURTESY OF ENCANA

▪ Well Completion

After a well is drilled, it must be completed before it can begin producing. There are three main steps in the completion process. The first step is allowing crude oil into the well so that it can be brought to the surface. The second is making sure water does not get into the well, and the third is keeping underground rock out of the well.

Completion is not done the same way for all wells. Deciding what to do depends on a number of factors, including the size and shape of the petroleum reservoir, the surroundings of the reservoir, and the kinds of rocks and petroleum the reservoir contains.

Petroleum is contained within rock formations. The nature of these formations affects the way petroleum is pumped from the ground. There are two characteristics that are very important to predicting how the petroleum will flow—porosity and permeability. Knowing if the pores connect to each other is important, since these connections are what allow petroleum to flow to the well. Even though a rock formation is very porous, if it has no permeability, the petroleum will be difficult to extract.

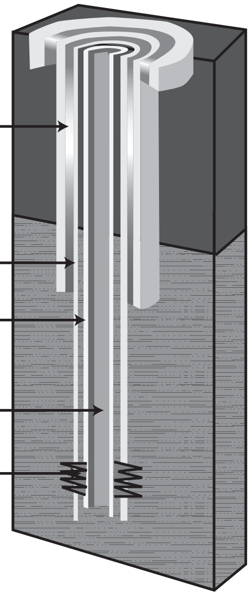
Most petroleum formations also contain water near to or mixed in with the petroleum. The amount of water is often described as the saturation of the well. Producers must be sure to separate this water out of the crude oil. They must also be sure to avoid contaminating nearby ground water, land, and underground aquifers.

The amount of pressure in a formation is another factor that is very important. Since petroleum extraction removes mass from the Earth, the stability of the reserve is something that must be considered. While some formations can maintain their shape when petroleum is removed, others cannot. These formations must be stabilized, allowing them to remain open for fluids to flow.

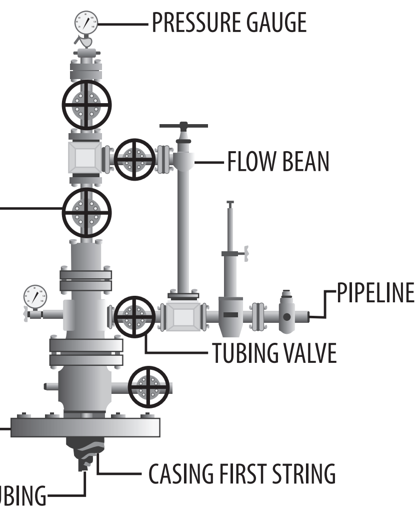
The last issue to be considered is how well the reserves are connected. **Compartmentalization** is a situation in which the petroleum from one part of the reserve cannot flow to another part of the reserve. There may be faults in the ground that disconnect the layers, or pores from one section may not be connected to other sections because of low permeability. There can also be streaks of other types of rock that the petroleum cannot easily pass through between the well and the petroleum, or there may be other barriers in the way of the flow.

Once all these issues are taken into consideration, completing the well may begin. To start completion, the well must be open so that petroleum can flow into it.

Casing Strings



Well Christmas Tree



What Happens When The Well Runs Dry?

Individual oil wells will eventually stop producing petroleum. When this happens, environmental and industry standards mandate the procedure for closing a well. Some of the steps required include cementing the well closed, removing equipment, and regrading the soil to return it to a state as close to the original as possible.

Because petroleum is a nonrenewable resource, at some point no new reserves will be located, and what is available at the time will limit how much petroleum can be produced. **Peak oil** is defined as the point in time when the maximum production of petroleum will be reached. When peak oil is reached, petroleum production will steadily decrease. If technology advances and the discovery of additional reserves of petroleum and natural gas do not keep up with demand, the U.S., and the rest of the world, will face a serious energy crisis.

▪ Casing the Well

Drill pipe does not stay in the well after it is drilled. It is replaced with longer, wider casing pipe, which is used to line the well. Usually, casing a well begins before the end of the drilling process. There are often several layers of casing close to the top of the well. Casing the top of the well occurs as the drill continues to dig deeper into the ground. The final and deepest casing is placed in the well after drilling is complete.

The rock around the well is crushed to allow the petroleum to flow freely. Shooting nitroglycerin and shattering the rock in the immediate area can crush the rock. The side of the well, or the casing, blocks petroleum from getting into the well itself. At the levels where petroleum is present, the casing is perforated to let petroleum flow more easily into the well. Perforating the casing is done by shooting a very thin, fast jet of fluid to penetrate and perforate the casing.

▪ Cementing

Once casings are in place, cement is used to fill in the gap between each of the casing pipes and the well wall. Drilling mud is pumped out of the well as cement is pumped in. As the cement is pumped in, the casing is slowly rotated to create a better bond with the cement.

▪ Production

Once the wells have been completed, they can go into production. Production wells do not have the complex, above ground structures that are in place during drilling. Instead, the wells are capped with smaller units. Ideally, petroleum is extracted using natural drive, which means there is enough pressure in the well to move the petroleum to the surface and no pumping is needed. Wells with natural drive have "**Christmas trees**" above ground. A Christmas tree, in the petroleum industry, is a series of valves and gauges used to measure and control the flow and pressure of the well.

Other wells do not have enough natural drive to move petroleum out of the earth. They must use pumps to artificially lift the petroleum to the surface. Typically, this is done with a sucker-rod pump, sometimes called a **horse head pump** because of its shape. Using one-way valves underground near the petroleum formation, the pump draws, or sucks, petroleum to the surface. As the horse head pump above ground goes up and down, valves below lift the petroleum. Pumps may run for only a few hours each day to avoid distorting the way the fluids are distributed underground. Many wells produce only a few barrels of petroleum a day.

In a well that has a lot of pressure, a **blow out preventer**, or BOP, is used to gain control of fluid pressure and prevent accidents at the surface. A BOP includes monitors to ensure the well is operating correctly and a set of controls that react to any unexpected pressure change. If there is too much pressure, the man-made elements of the well could be forced out the top of the well or fire could occur.

HORSE HEAD PUMP

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To monitor a well's progress, comprehensive data logs track a number of different factors. Radioactive, electric, mechanical, and sonic tools are just some of the ways wells are studied. If monitors indicate unusual well behavior, engineers investigate and attend to the problem.

▪ Subsea Operations

In offshore operations, well completion and production are similar to onshore, but they take place below hundreds or thousands of feet of water. Well heads or caps must be resistant to corrosion by saltwater and must be able to withstand the pressure deep in the ocean. Well operators do not regularly visit the ocean floor to check on the well caps. Instead, sensors are placed on the well caps so that the wells can be monitored from the platform. Advanced technologies such as Remote Operating Vehicles, or **ROVERS**, can make robotic repairs to the well by operators on the platform using remote controls.

The petroleum is piped to an offshore processing platform where it is combined with petroleum from other wells before being cleaned and sent to a **refinery**. There is a limited amount of space on an offshore platform to store new petroleum, so all of the operations must be carefully coordinated. Production supervisors oversee the entire operation of an offshore rig to make sure operations are moving smoothly.

▪ Cleaning the Petroleum

Once petroleum has been brought to the surface, it must be cleaned. Refineries have specific standards that they require suppliers to meet before they will accept the petroleum. Producers usually clean their petroleum on site, near the pump. If a producer has multiple wells near each other, there may be one processing facility for a number of wells.

Petroleum, natural gas, and saltwater can often come up through the well mixed together. The simplest way to separate out the different materials is in settling tanks. Because gas is very low in density, it will rise to the top of the tank. The separation of petroleum and water, however, is not quite as simple.

Petroleum and water naturally separate because of their differences in polarity. Some molecules are **polar**, and some are **nonpolar**. A polar molecule is one where the electrons are not shared evenly among the atoms, and slight differences in electrical charge develop within the molecule. Nonpolar molecules have an even distribution of electrons, and therefore have no difference in electrical charge in the molecule. Polar compounds will dissolve polar compounds, and nonpolar compounds will mix with nonpolar compounds. This is why vegetable oil, which is nonpolar, will not mix well with water, which is polar.

When petroleum and water are mixed together, they can be difficult to separate. This is true for household vegetable oil and tap water and it is true for crude oil and saltwater. Refineries require that the petroleum contain no more than one percent water. Waiting for the petroleum, saltwater, and gas to separate naturally in tanks can take a long time, so other methods are often used.

Pressurized **separators** that have a higher capacity and separate more quickly can also be used. Inside these separators, controlled pressure and heat are introduced to aid the separation to collect denser liquids at the bottom, and gases are piped out the side. Separators do a good job of separating petroleum and gas, but more processing is needed to separate the petroleum and water.

OFFSHORE OIL RIG

To remove excess water, thermal energy is applied with a heat-treater. The heat-treater causes the droplets of water suspended in the petroleum to come together, creating larger drops that are easier to remove from the petroleum. Water-free petroleum is removed from the top and the water sinks to the bottom.

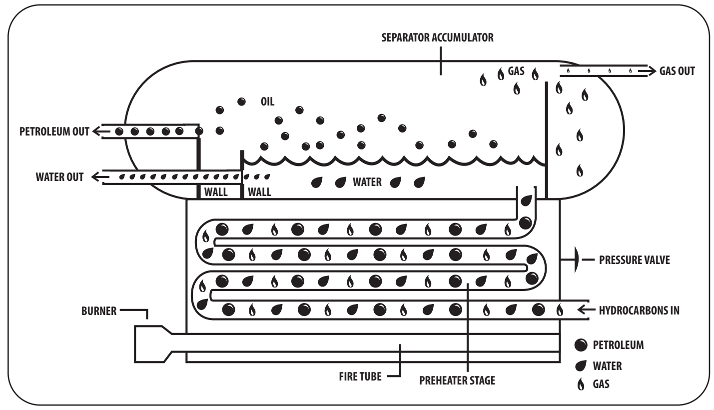
Retrieving Natural Gas

Because natural gas is formed in much the same way as petroleum, it is also found using the same technology and techniques as petroleum. However, locating a productive natural gas well is less certain than with petroleum. Exploring for natural gas deposits is a high-risk, high-cost enterprise. Natural gas wells average 6,300 feet deep and can cost hundreds of dollars per foot to drill. About 60 percent of the exploratory wells produce gas; the others come up dry. The odds are better than 60% for developmental wells—wells drilled on known gas fields. Natural gas can be found in pockets by itself or in petroleum deposits.

Natural gas may also come from several other sources. One source is coalbed methane, natural gas found in coalbeds. Until recently, coalbed gas was just considered a safety hazard to miners, but now it is a valuable source of natural gas.

Another source of natural gas is the gas produced in landfills. Landfill gas is considered a renewable source of natural gas since it comes from decaying garbage. The gas from coalbeds and landfills accounts for under ten percent of the total gas supply today, and experts predict this figure will increase. The gas recovered from landfills is usually burned on the landfill site to generate electricity for facility operations, however some landfill gas sites are large enough to generate electricity to supply utilities.

SEPARATOR



Methane Hydrates

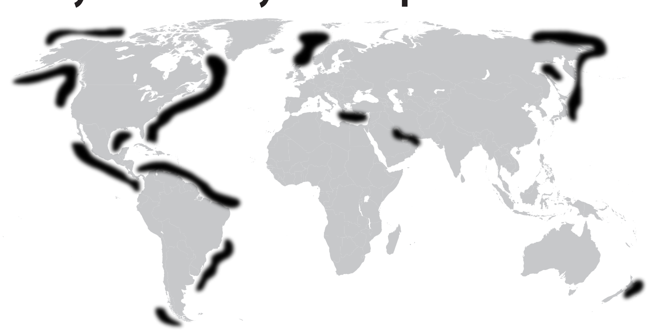
In the 1930s, miners trying to extract natural gas noticed their pipes becoming clogged in low temperatures with an icy substance. Further study revealed that the substance was a combination of methane trapped in ice crystals, and has come to be known as methane **clathrate** hydrate, or more commonly, **methane hydrate**. In the 1960s, geologists learned that methane hydrates exist naturally at the bottom of the ocean along continental shelf boundaries, and in the frozen extremes of the two poles.

Methane is a natural by-product of bacterial decay of organic matter, such as dead marine plants and animals. When this occurs deep in the ocean, or when methane from rock layers deep beneath the ocean seeps out, the methane becomes trapped in the structure of a methane hydrate.

Scientists at the Spallation Neutron Source at Oak Ridge National Laboratory have studied the structure of methane hydrates and have learned much about how they are formed and organized, and how the interaction between the nonpolar methane and polar water occurs. This will help further research into how water and hydrocarbon molecules interact, and could lead to a new way of sequestering the carbon dioxide produced when methane is burned, creating an "energy cycle" where methane is extracted from ice, burned, and the carbon dioxide is encased in clathrate crystals.

Many experts believe that methane hydrates are an excellent source of energy for the future. Methane molecules are very closely packed together in the cage-like structure of a methane hydrate, and the amount of energy concentrated is very high. Furthermore, many scientists believe vast quantities of free methane lie beneath the methane hydrate layers. The challenges lie in recovering the methane without allowing it to escape into the atmosphere. Because methane is a greenhouse gas, like carbon dioxide, any process that allows significant amounts of methane to be released into the atmosphere would be considered environmentally harmful.

Likely Methane Hydrate Deposits



Shipping Crude Petroleum

Petroleum wells are located above petroleum-bearing formations, wherever they are found. Refineries are usually near petroleum consumption markets, though many are located near major petroleum producing areas as well. There are different ways to get the petroleum from well to refinery.

Much of the petroleum we use is shipped via pipeline. Petroleum pipelines move crude petroleum from petroleum platforms offshore to refineries onshore. Pipelines can also move petroleum products between regions of the United States. Pumping stations along the pipelines are located every 60 to 100 miles to keep the petroleum flowing.

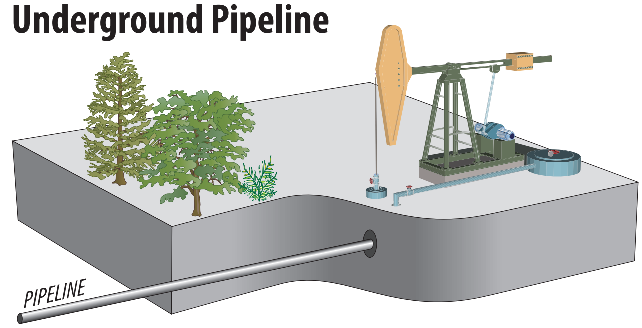
A pipeline must be kept clean. To clean the inside of a pipeline, an instrument called a **pig** is used. This instrument is shaped like a bullet and scrubs the wall of the pipeline. More advanced pigs, called smart pigs, use cameras to monitor the pipe for flaws.

For longer distances, petroleum is put in tanker trucks or moved by sea on petroleum tankers. Petroleum produced in Venezuela, for example, is carried to the U.S. in petroleum tankers. This petroleum is off-loaded at a refinery to be turned into useful products. Petroleum tankers have two hulls, or shells, to help prevent petroleum spills.

In most cases when petroleum is shipped by tanker, the crude oil travels through both pipeline and tanker. One example is petroleum produced on the Northern Slope of Alaska. This petroleum field is very far north, near the Arctic Ocean. Instead of building a port to bring tanker ships into these treacherous waters, a pipeline was built to carry the petroleum to a more easily reached port in the southern part of Alaska.

After transportation by petroleum tanker or pipeline to a refinery, much of the crude oil is placed in storage facilities or **tank farms**. These large cylinders hold the crude oil until the refinery is ready to process it.

Underground Pipeline



Transporting Natural Gas

How does natural gas get to you? Usually by pipeline. Over 3 million miles of pipelines link natural gas wells to cleaning plants to major cities across the United States. Natural gas is sometimes transported thousands of miles by pipeline to its final destination.

A machine called a **compressor** increases the pressure of the gas, forcing the gas to move along the pipelines. Compressor stations, which are spaced about 50 to 100 miles apart, move the gas along the pipelines at about 15 miles per hour.

Some natural gas moved along this pipeline highway is temporarily stored in huge underground reservoirs. The underground reservoirs are typically filled in the summer so there will be enough natural gas during the winter heating season.

Eventually, the gas reaches the city gate of a local natural gas utility. The pressure is reduced and an odorant is added so leaking gas can be detected. Local gas companies use smaller pipes to carry gas the last few miles to homes and businesses. A meter measures the volume of natural gas a consumer uses.

Uses of Natural Gas

Just about everyone in the United States uses natural gas and the electric power sector is a close second, behind industry, for use of natural gas. Industry is one of the biggest users of natural gas. Industry burns natural gas for thermal energy necessary to manufacture many of the products we use every day. Natural gas is also used as **feedstock**—an ingredient in fertilizer, glue, paint, laundry detergent, and many other products.

Natural gas can be used to generate electricity, and the electric power sector is a close second behind industry for use of natural gas. Many utilities are building new power plants or converting old plants into sites that burn natural gas. It is cleaner burning than coal, and natural gas plants can produce electricity quickly when it is needed for periods of peak demand.

The residential sector of our economy is the third biggest user of natural gas. More than fifty percent of homes use natural gas for heating, and many also use it for cooking and heating water. Commercial buildings use natural gas, too. Commercial users include stores, offices, schools, churches, and hospitals.

A small amount of natural gas is used as fuel for automobiles. Natural gas is cleaner burning than gasoline, but vehicles must have special equipment to use it. Many city buses and vehicles used in national parks operate on compressed natural gas, or CNG.

From Oil Pump to Gas Pump: Refining Transportation Fuels

Before petroleum can be used, it must be sent to a refinery, where it is separated into its components. At the refinery, a process called **fractional distillation** is used to separate the molecules by another physical property, the **boiling point**. In the **distillation** or **fractioning tower**, smaller molecules, with lower boiling points, move to the top of the column, while the largest molecules, with the highest boiling points, collect at the bottom.

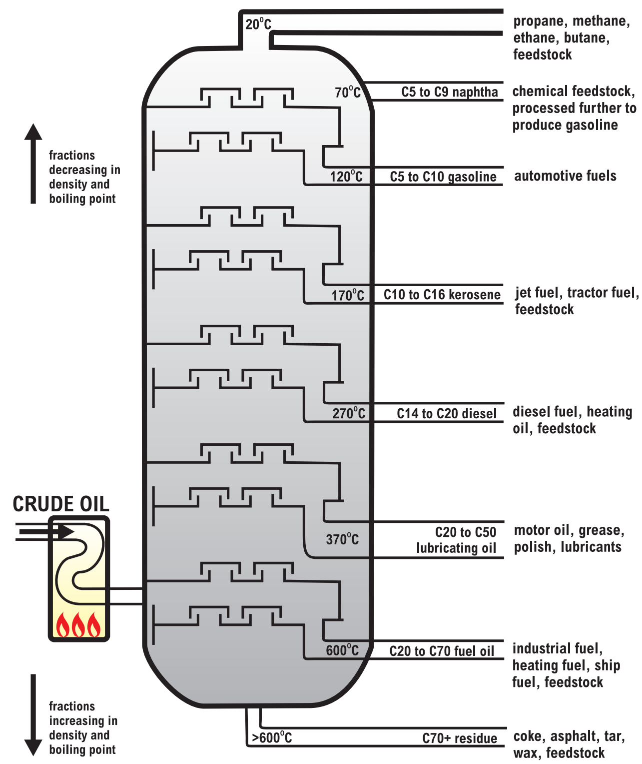
Compounds that will be used in transportation fuels, such as gasoline and jet fuel, are sent for further refining before being distributed to fueling stations. There are three main types of processes that are used in this refining.

NATURAL GAS PIPELINE

Natural gas pipelines transport large quantities of natural gas to consumers.

OIL REFINERY

Fractional Distillation



Cracking breaks long hydrocarbon chains into smaller ones. **Unification** combines small chains into longer ones. **Alteration** rearranges pieces of hydrocarbon chains to make different hydrocarbons.

Cracking can be done in a number of different ways. One method is thermal cracking. **Thermal cracking** uses very high temperatures to break apart long chains of hydrocarbons. This can be done using high temperature steam. Cracking can also be done by heating the residue from distillation towers to very high temperatures until it separates into useful parts. This process is also known as **coking**, because the material that is left after all of the useful hydrocarbons are removed is **coke**, a hard, porous carbon material. Coke is used by heavy industry, such as iron and aluminum manufacturing. Another way that long hydrocarbon chains are broken is through catalytic cracking. A **catalyst** is a material that increases the rate of a chemical reaction, but is not a part of the chemical reaction. **Catalytic cracking** is used to change heavy diesel oils into diesel fuel and gasoline.

When smaller hydrocarbons are combined to make larger ones through unification, they usually undergo a process of **catalytic reforming**, a process that converts **naphtha** into aromatics. Aromatics are cyclic hydrocarbons, meaning the carbons form a ring rather than the simpler straight chain of hydrocarbons. Their name is derived from their distinctive sweet smell. Aromatics are a very important class of petrochemicals and are typically blended into gasoline and used to manufacture many different products. The most common aromatics are benzene, toluene, and zylenes. In addition to aromatics, the main by-product of catalytic reforming is hydrogen gas.

Alteration is the rearrangement of molecules in a hydrocarbon to create a more useful hydrocarbon. Usually this is done with **alkylation**, a process in which hydrocarbons are mixed with a catalyst and an acid to create hydrocarbons that are more branched, rather than straight chains. Branched hydrocarbons burn more smoothly than straight chain hydrocarbons. Adding branched hydrocarbons to gasoline improves its octane rating and reduces engine knocking.

Beyond the Gas Tank

Petroleum goes into much more than just the tanks of our cars and airplanes. Petroleum is used to make many of the products we use every day. It is well known that plastics are made from petroleum products, but that is only the beginning. Your toothbrush, toothpaste, shampoo, and even your contact lenses are made from petroleum, as are carpeting, CDs, the ink in your pen, and medical devices such as prosthetic heart valves.

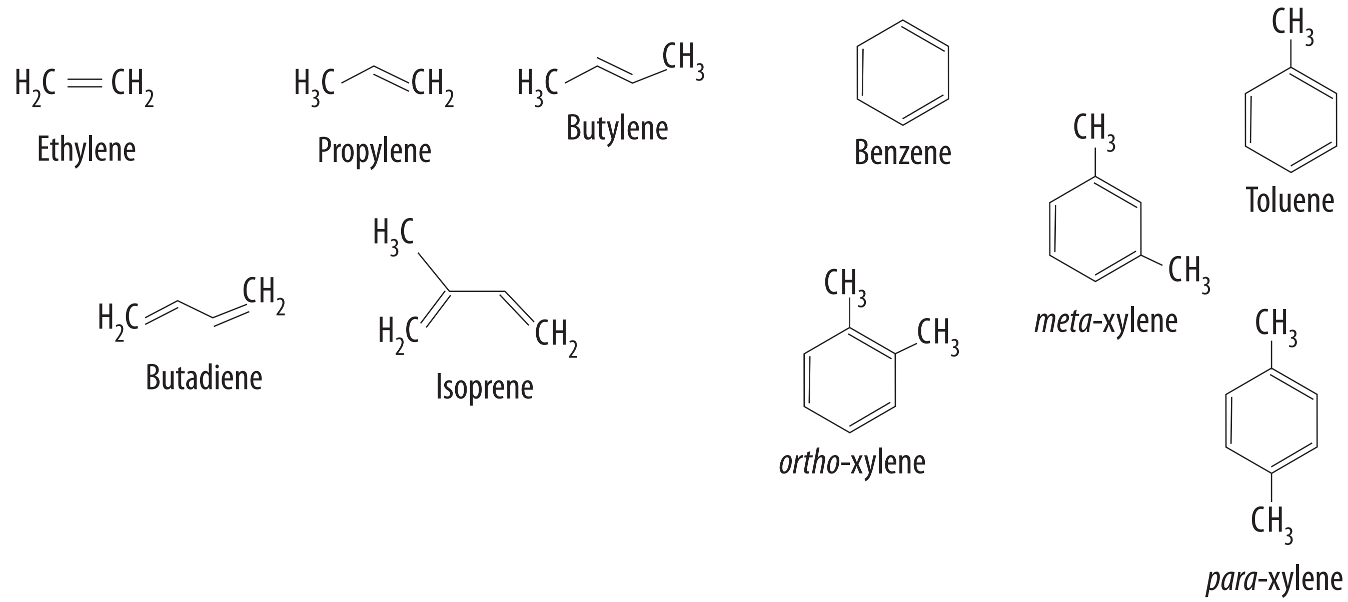
Chemical plants take refinery products and manufacture the products we use. There are many different kinds of chemical plants ranging in size from one to two items produced to many different products. The largest plants can produce over 5 billion pounds of product each year. Large chemical plants are continuously in operation every day of the year. Many of these plants are automated with new technology and need fewer people than in the past to run them.

To get the products that are familiar to us, feedstocks, or raw materials, must be processed. Different products have different steps that are needed. Many products are made from more than one feedstock, which are combined in different ways to produce a variety of products.

Besides being used as fuel additives, aromatics are used to make plastics and **polymers**. These materials go into products such as paint, textiles, building materials, and leather alternatives.

Another important category of compounds produced from petroleum refining, olefins, are hydrocarbons that contain one or more pairs of carbon atoms linked by a double bond. Typical examples include ethylene and propylene. Olefins are obtained by cracking petroleum fractions at high temperatures. Another word for olefin is **alkene**. The simplest olefins are the basis of the petrochemical industry. They are used to produce plastics, industrial solvents, and chemicals used in other applications. A number of familiar products come from these petrochemicals, including plastic bags, paint, tires, and plastic bottles.

Common Olefins and Aromatics



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Economics and Policies

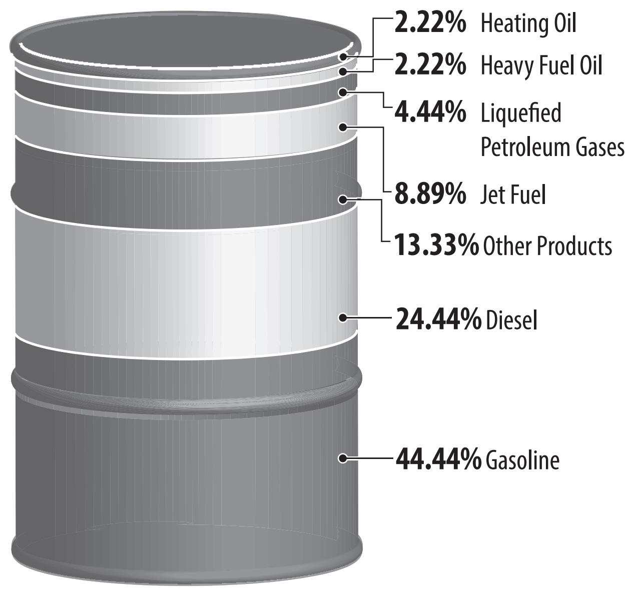
The prices of petroleum and natural gas have risen significantly in the last decade. The increase is due to both an increase in demand worldwide as well as a decrease in supply. Demand in the U.S. has increased, but developing economies in other countries have also increased the amount of oil and natural gas they use. As the most accessible reserves have been extracted, it becomes more difficult and expensive to continue production of these valuable resources. Currently the U.S. is importing about 40% of its crude oil supply. The U.S. also imports a very small amount of natural gas, but the majority of natural gas is produced domestically. The U.S. has recently begun exporting natural gas as LNG. Overall, the U.S. imports about 22 percent of its energy.

There is a wide variation in cost of petroleum and natural gas around the world due to government **subsidies**, taxes, political and social ideologies, as well as distance from petroleum sources. **Fluctuations** in the price of petroleum are also due to our dependence on foreign supplies and uncertainty of future petroleum production. The prices of petroleum and natural gas affect the economy in many ways including the cost of transportation, electricity, the vast array of products made from petroleum and natural gas, heating and cooling, and even our food supply.

Across the U.S., the petroleum and natural gas industries provide over 10 million jobs and are responsible for nearly 8% of our gross domestic product. The industries are major employers and economic developers that are important to the economic health of our country and to our national security.

Politics play an important role in the development and regulation of petroleum and natural gas. As a nation, we rely heavily on these sources for our energy and manufacturing needs. Politically, the use of petroleum and natural gas raises concerns for national security, pollution, economics, and international relations. Decisions made by Congress impact the future production and consumption of petroleum and natural gas.

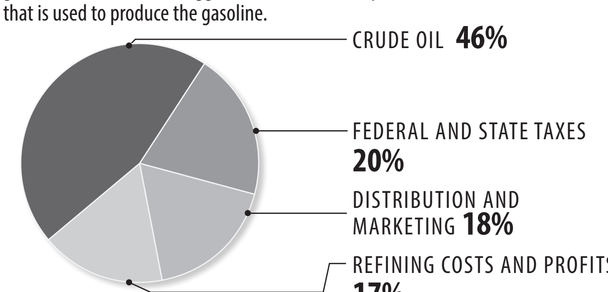
Products Produced From a Barrel of Oil, 2017



Data: Energy Information Administration

Factors in Gasoline Pricing, 2018

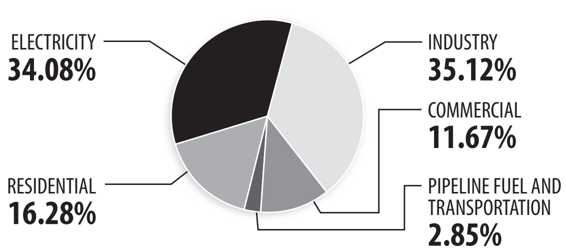
In June 2018, the average retail price for a gallon of regular grade unleaded gasoline was $2.73. The biggest factor in the total price is the cost of crude oil that is used to produce the gasoline.



Data: Energy Information Administration

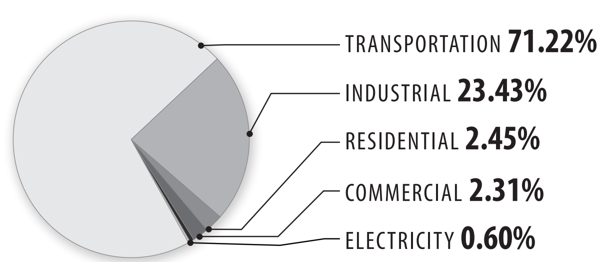
*Total does not equal 100% due to independent rounding.

U.S. Natural Gas Consumption by Sector, 2017



Data: Energy Information Administration

U.S. Petroleum Consumption by Sector, 2017



Data: Energy Information Administration

*Total does not equal 100% due to independent rounding.

What Is LNG?

Liquefied natural gas (LNG) is natural gas that has been cooled until it becomes a liquid. LNG is made by cooling natural gas to -260 degrees Fahrenheit (or -162.2 degrees Celsius). At this temperature, natural gas changes state into a liquid, and its volume is reduced 600 times. LNG, like natural gas, is odorless, colorless, noncorrosive, and nontoxic.

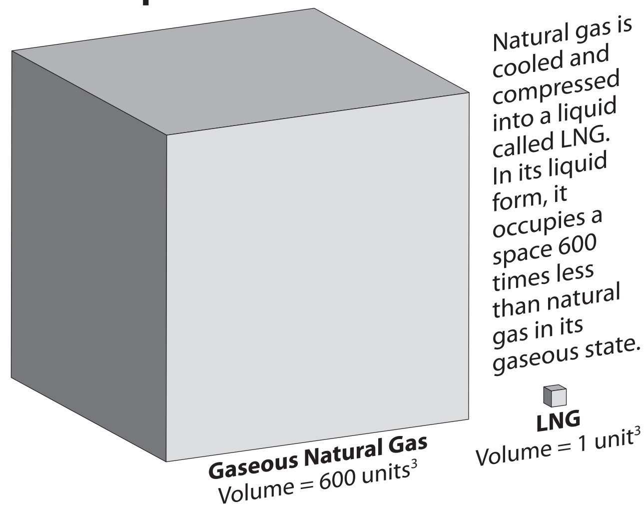
Production

The process for making LNG starts the same as producing natural gas. The raw feed gas, or natural gas that has come from the well, must be processed to separate out impurities, such as dirt, hydrogen sulfide, and carbon dioxide. Next, the gas is cooled to allow water to condense and be removed. Additional dehydration is sometimes needed to ensure even small amounts of water vapor are not present. Then the gas is separated into its various components such as propane and butane.

Once the natural gas is clean and dry, it is ready for the **liquefaction** process. Turning natural gas into LNG takes place through **heat exchangers** that cool the gas. Gas circulating through aluminum tube coils is cooled by a compressed **refrigerant**. As the refrigerant vaporizes, it cools the gas in the tubes. The refrigerant returns to a **compressor** while the LNG is pumped to an insulated storage tank.

The United States has recently begun exporting LNG. LNG is produced in large quantities overseas. The top countries that exported LNG in 2017 were Qatar, Australia, Malaysia, Nigeria, and Indonesia. The United States has been producing enough natural gas that a few of its import terminals are able to act as export terminals, and is now in the list of top ten exporters of LNG. One example of a site with this ability is Sabine Pass on the border of Texas and Louisiana. The first LNG cargo was loaded at Sabine Pass in February, 2016. Maryland's Cove Point Terminal became active in early 2018. Several others are in various stages of approval and construction.

LNG Compression



LNG is transported overseas by ship. Many of these ships have a membrane hull design.

Transporting and Storing

After liquefaction, LNG is stored in insulated tanks. These tanks are specially designed to keep the interior at extremely low temperatures but the exterior the same temperature as the ambient air or ground. The inner layer of the tank is a steel **alloy**. Then there are layers of insulation, stainless steel, and additional insulation. The outer layer is reinforced concrete with heating ducts laced throughout to prevent the ground from freezing. The walls of an LNG storage tank can be as much as five-and-a-half feet thick.

Some LNG storage tanks have a containment feature to safeguard against leaks. In these tanks, both the inner and outer walls are capable of holding the LNG. However, most LNG storage facilities in the U.S. use another approach. The storage tank is surrounded by a dam or dike made of soil that provides secondary containment.

LNG is then transported world-wide using ships with specifically designed hulls. The current world LNG fleet consists of over 350 ships. Modern LNG ships follow two basic designs. The membrane design features multiple tanks with linings made of thin nickel-steel alloy. These tanks are integrated into the hull of the ship, which can be more than six feet thick. The spherical design has round storage tanks that sit on supports on the hull.

Once LNG reaches its destination, pumps transfer it to insulated storage tanks. When the LNG is needed the liquid is warmed and quickly becomes a gas; this is called **regasification**. Two types of systems are typically used for regasification. Ambient temperature systems use heat from surrounding air or sea water. Above-ambient temperature systems burn a fuel to indirectly warm the liquid using a fluid bath. After regasification, the natural gas can join the network of pipelines used to transport it to consumers.

Storage and transportation of LNG make for its biggest advantages and its biggest disadvantages. Once liquefied, LNG takes up 1/600th the amount of space as it did as natural gas. This is like comparing the volume held in a beach ball to that inside a ping pong ball. This is a great advantage for storage and transportation. More can be stored and moved at one time. Also, LNG can be transported over routes or to locations that do not have natural gas pipelines.

However, because the tanks for storage must be designed for the -260° Fahrenheit temperature (-162.2°C) inside and ambient temperature outside, LNG has distinct disadvantages when compared to natural gas for storage and transportation. Storage tanks must keep the LNG very cold and ships and trucks must be specially made for LNG storage.

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An LNG storage option utilizes underground **salt caverns**. Rather than offloading the LNG from the ship into above ground storage tanks, it is pressurized, warmed to 40 degrees Fahrenheit, and then injected into underground salt caverns. This method is called the **Bishop Process**. This process decreases the offloading time of LNG tankers and increases the storage capacity potential of LNG. Suitable salt cavern locations have been located in the U.S., with over 2,000 currently being used for storage and delivery of fossil fuels.

U.S. LNG Terminals and Storage Facilities

Currently the U.S. has 12 terminals for importing LNG – 9 on the mainland and offshore near Boston, Massachusetts, and in Puerto Rico. The mainland terminals are located in Georgia, Louisiana, Maryland, Massachusetts, Mississippi, and Texas. Several more facilities are in approval or construction processes both on the mainland and offshore. Several are also equipped for export. In 2012, the U.S. imported 175,000 million cubic feet (Mcf) of LNG. In 2017, however, the U.S. imported just about 78,011 Mcf. The reason for the major decline is due to the growth of domestic natural gas production. The LNG imported comes from Trinidad, Nigeria, and Canada.

If terminals in the U.S. import natural gas that is not sent to market, the U.S. can re-export the LNG to other countries. In this instance, LNG is brought into a U.S. terminal, stored at pressure, and shipped back out as LNG. In 2017, the U.S. re-exported 422 Mcf of LNG to Mexico. Re-exporting allows terminals to stay active, in spite of the domestic availability of natural gas. However, many of the existing LNG import facilities are in the process of becoming export terminals, pending their approval and construction process. These facilities would then be able to liquefy domestically produced natural gas on-site and ship it to other countries. Of the facilities set to export, in 2017 707,542 Mcf was exported.

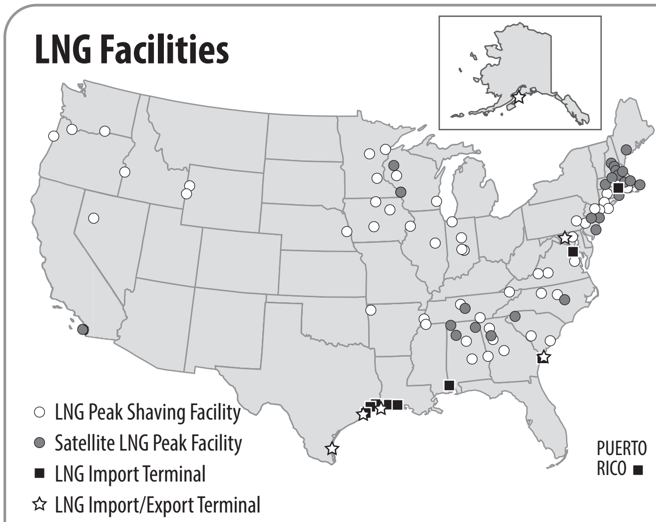
Besides the mainland and offshore terminals, there are more than 100 facilities located throughout the U.S. that store or supply natural gas to the surrounding areas. Some of these facilities are **peak shaving facilities**. Consumer demand for natural gas rises and falls based upon the season. Peak shaving facilities are able to store natural gas as LNG and provide a reliable supply of natural gas at times when it is at its peak demand, thus lowering or shaving the peaks in demand. The majority of the peak shaving facilities are located in the Northeast, Midwest, and Southeast. Peak shaving facilities will divert natural gas from the pipeline at off-peak times, liquefy it, and store it until needed. When demand peaks, the LNG is regasified, and distributed to customers through the regional distribution lines. Other facilities are termed as **satellite** storage facilities. These facilities truck LNG from an import terminal and store it in tanks until it is needed.

Using LNG

For the most part, LNG is used the same way that regular natural gas is used, primarily by industry and in generating electricity. However, because of its condensed state, LNG has a few applications that pipeline-delivered natural gas does not. A modified car with an insulated fuel tank can use LNG the way they use CNG. In 2014, the most recent data available, nearly 4,000 vehicles in the U.S. used LNG.

LNG is beginning to be used in rural areas as an alternative to **propane**. Additionally, LNG can meet some **distributed energy** needs. Distributed energy is generated and stored near the point of use. While natural gas is a popular choice for distributed energy systems, not all locations are within the pipeline distribution system. LNG can bring fuel to an isolated facility that has its own energy system.

LNG Facilities



Data: Federal Energy Regulatory Commission

LNG Terminal Profile: Elba Island, Georgia

One of U.S. mainland LNG terminals, Elba Island is located near Savannah, Georgia. It receives, stores, and regasifies natural gas. Elba Island opened in 1978 and was fully operational for four years. From 1982 to 2001, however, it operated in a limited capacity. Since then, Elba Island has been fully operational.

Currently, Elba Island can store 11.5 billion cubic feet of LNG. With an average daily use in Georgia of 1.9 billion cubic feet, and a possible daily output of 1.8 billion cubic feet, Elba Island could provide the state with all its natural gas needs for just under a week. In fact, when hurricanes Katrina and Rita decimated the Gulf Coast region and disrupted energy distribution, Elba Island was able to double its output to provide customers with natural gas. With the increase of natural gas and LNG use in the U.S., Elba Island is expanding its storage and output capacity to export LNG. When expansion is complete and beging in 2018 the facility could export up to 350 Mcf per day.

Of the half million people employed by utilities nationwide, over 100,000 are in natural gas distribution. More than 50 people are employed just at Elba Island. At Elba Island, one may find gas plant operators that operate gas liquefying equipment, operate compressors to control gas pressure in transmission lines, and coordinate injections and withdrawals at storage fields. Additionally, engineers, maintenance workers, dock workers, environmental or regulatory specialists, LNG technicians, and plant supervisors all can be found at Elba Island.

The Global LNG Market

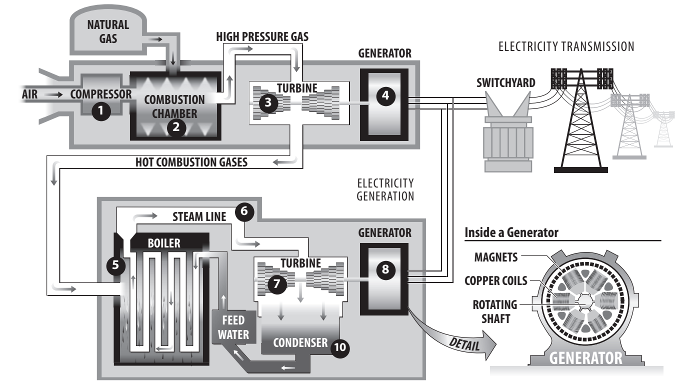
The U.S. is not the only country that imports natural gas. Fortunately, global natural gas reserves are vast, estimated at about 6,900 Tcf. This is about 50 times the volume of natural gas used worldwide in 2017. However, much of the reserves are considered **stranded** due to geographic locations and distance to consuming markets. Converting natural gas to LNG allows stranded gas to move to useful markets.

The global LNG market is divided into geographic regions. The Atlantic Basin includes trade in Europe, northern and western Africa, and the U.S. Eastern and Gulf Coasts. The Pacific Basin involves trade in South Asia, India, Russia, and Alaska. Middle Eastern countries typically export LNG to the Pacific Basin, but some cargoes are shipped to Europe and the U.S. LNG trade in Middle Eastern countries is growing to the point that some experts consider the Middle East to be the third LNG geographic trade region.

LNG trade within the Atlantic and Pacific Basins differs. Prices are generally higher in the Pacific Basin. However, peak seasonal demands can cause short-term price increases in the Atlantic Basin. Importing countries in the Pacific Basin are almost entirely dependent upon LNG. Countries such as Japan and South Korea, which are the largest importers, use LNG to meet over 90 percent of their natural gas needs. Importing countries in the Atlantic Basin rely mostly upon domestic natural gas supplies and use LNG to meet the difference between production and demand. For example, LNG accounts for less than two percent of U.S. natural gas supplies.

More countries are entering the LNG global market every year. Countries already active in LNG trade are increasing their capacity by either constructing new LNG terminals or expanding existing plants. Growth within the global LNG market is being driven by declining natural gas production in gas consuming countries, and the desire of gas-producing countries, such as Russia, to maximize their resources.

How Natural Gas Generates Electricity in a Combined-Cycle Power Plant



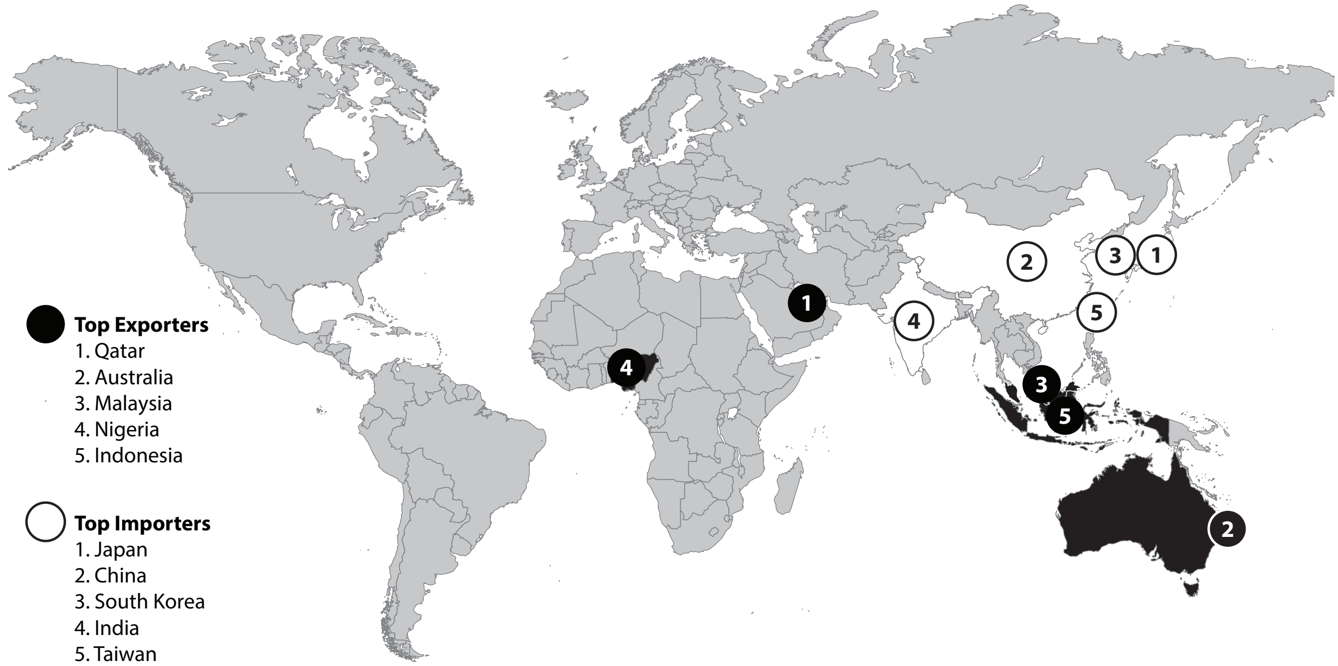
A **generator** is a device that converts mechanical energy into electrical energy. All electric power plants have a generator. What differs from plant to plant is the fuel source and method used to spin the shaft that will spin the generator to produce an electric current.

Electricity generated from natural gas has steadily increased. Most new natural gas electric power plants are building highly efficient **combined-cycle** units. These units use both gas combustion turbines and steam turbines.

Gas combustion turbines have three main components: a compressor, a combustion system, and a turbine. The compressor **(1)** draws air into the machine. Here, the air is pressurized and pushed into the combustion chambers. The combustion system consists of fuel injectors and combustion chambers. A ring of fuel injectors puts a stream of fuel (natural gas) into the combustion chambers **(2)**. There the natural gas and air mix. The mixture is burned to produce a high temperature, high pressure stream of gas that moves to the turbine. In the turbine **(3)** the high temperature, high pressure gas expands causing blades to rotate. The rotating blades are connected to a shaft that spins the electromagnet in the generator **(4)**, producing electricity **(9)**. After the gas passes by the turbine, it is piped into a boiler **(5)** to produce steam.

Steam turbines have three major components: a boiler, a turbine, and a condenser. In the boiler **(5)**, a fuel is burned, such as natural gas. The heat turns water into steam **(6)** where it travels to a turbine. The steam moves the blades of the turbine **(7),** which is attached to the electromagnetic shaft of the generator **(8)**. The rotating electromagnetic shaft in the generator produces electricity **(9)**. After moving through the turbine, the steam goes through the **condenser (10)** where a coolant, often water, is used to turn the steam into a liquid so it can return to the boiler.

Top Exporters and Importers of LNG, 2017



Data: Energy Information Administration

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Climate Change

Combustion of anything high in carbon, including petroleum and natural gas, produces carbon dioxide. Carbon dioxide is one of many greenhouse gases. A **greenhouse gas** is one that is able to capture and hold significant amounts of thermal energy within its chemical bonds. The bonds of greenhouse gases are flexible, enabling them to absorb thermal energy, increasing the temperature of the atmosphere. Many scientists believe that increasing levels of carbon dioxide in the atmosphere, caused in large part by fossil fuel use, are having long-term effects on the global climate.

Figure 1—The radiant energy from the sun is absorbed and transformed to thermal energy on Earth. Greenhouse gases in the atmosphere absorb thermal energy. When more greenhouse gases are present, more thermal energy is absorbed.

Climate change is a global concept. Emissions from all of the nations of the world contribute to the global climate. Figure 2 below summarizes major greenhouse gas emissions. For more discussion on the global concentrations and effects of these emissions since the Industrial Revolution, download NEED's *Exploring Climate Change* guide from shop.NEED.org.

Figure 1

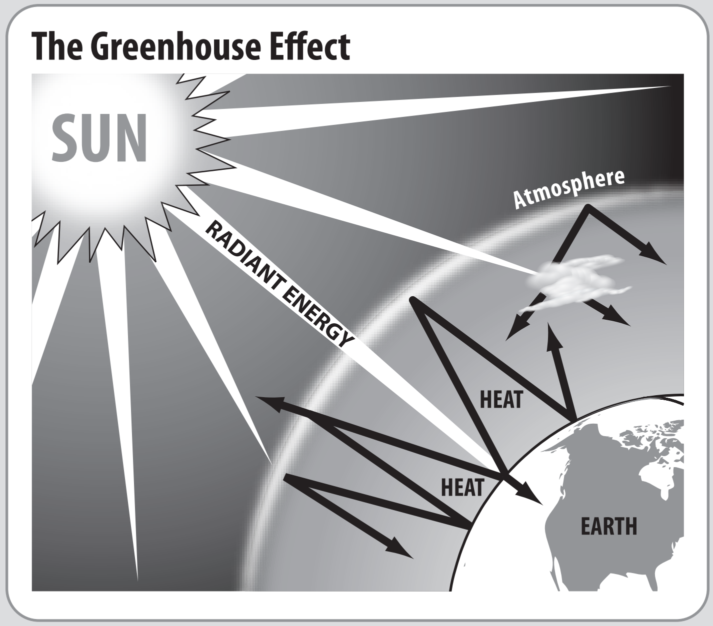
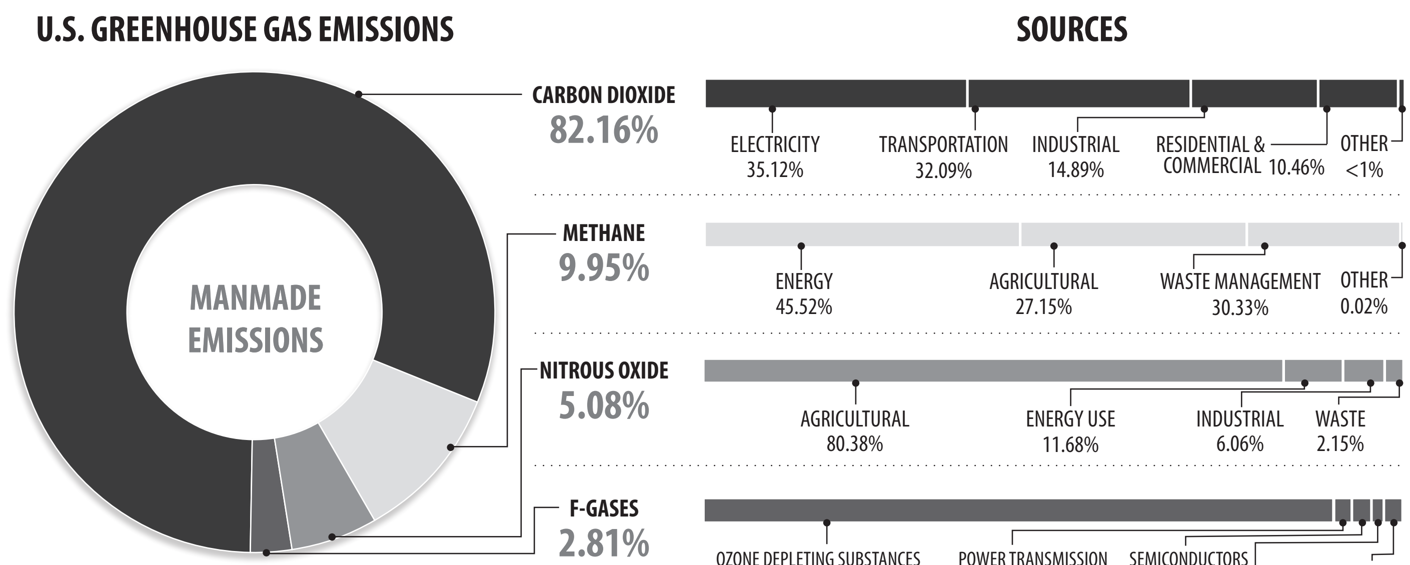


Figure 2—Carbon dioxide is not the only greenhouse gas produced by human activity. This chart shows the major greenhouse emissions produced in large part by human activity.



Data: U.S. Environmental Protection Agency
*F-gases include HCFCs, PFCs, and SF_6, which are used in many different industrial applications, including refrigerants, propellants, and tracer chemicals.
**EPA is not reporting more recent data on emissions presently.

Figure 3—Without human intervention, distribution of carbon throughout the Earth remains constant. Releasing carbon by burning fossil fuels, and decreasing plants' ability to remove it by changing land use, shifts the equilibrium toward greater strain on atmospheric conditions.

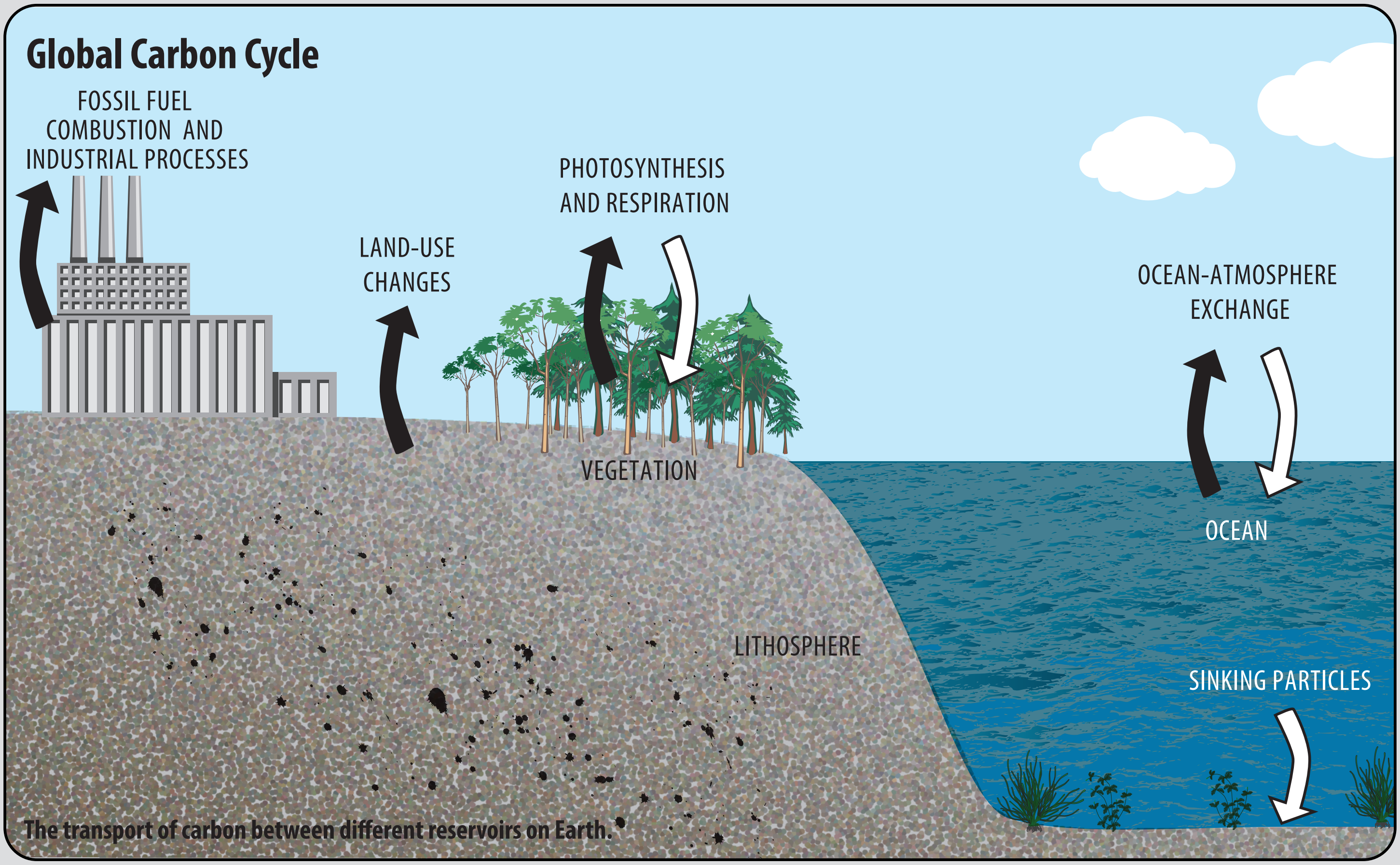
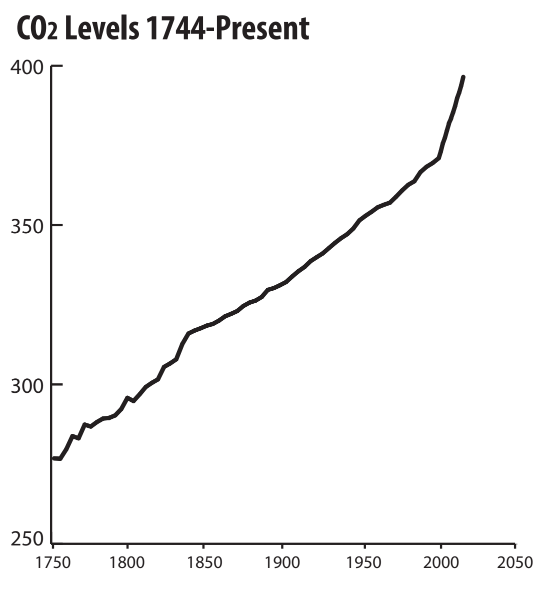
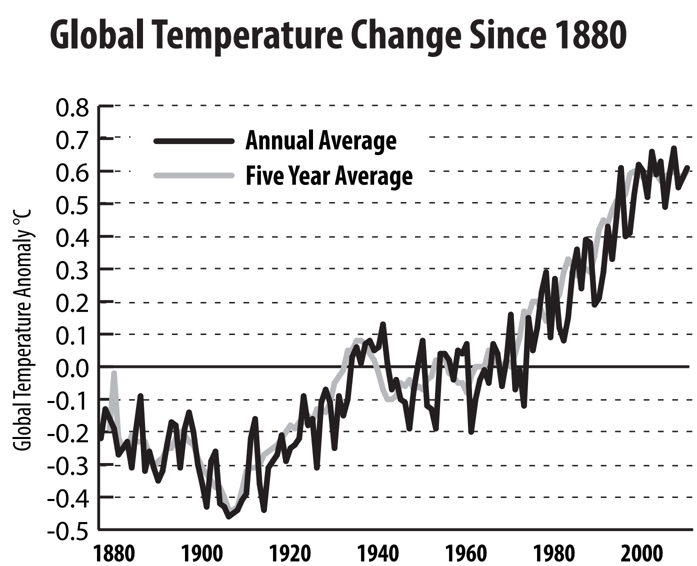


Figure 4—Since the Industrial Revolution began, fossil fuels have been providing most of the energy being used. Burning fossil fuels releases carbon dioxide, a greenhouse gas. Increases in greenhouse gas emissions cause temperatures to increase.





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Careers in the Petroleum and Natural Gas Industry

The petroleum and natural gas industry offers a variety of careers for individuals to work at its refineries, chemical plants, or on exploration and production facilities, both onshore and offshore. The following are just some of the career options available:

Process Technicians—members of a team of people that control, monitor, and troubleshoot equipment and focus on safety and environmental considerations.

Instrumentation Technicians—maintain, calibrate, adjust, and install measuring and control instruments necessary to ensure the safe, efficient operation of equipment.

Electricians—read blueprints that show the flow of electricity and maintain and repair the electrical and electronic equipment and systems that keep the facilities up and running.

Machinists—install, maintain, repair, and test rotating mechanical equipment and systems.

Geologists—explore the nature and structure of rock layers to piece together a whole picture of the subsurface in order to determine the best possible places to drill for petroleum and natural gas.

Petroleum Geologists—gather, process, and analyze seismic data and well data in order to locate drill sites for their companies.

Geoscientists—study the composition, structure, and other physical aspects of the Earth and are involved in exploration and production of petroleum and natural gas.

Petroleum Engineers—play a key role in determining the reservoir capacity (how much petroleum it might hold) and productivity (how much it produces) to design systems that move the petroleum from the wells (production process) through refining, where it gets cleaned up and converted into the energy we use.

Chemical Engineers—design chemical plant equipment and develop processes for manufacturing chemicals and products like gasoline, detergents, and plastics.

Mechanical Engineers—deal with the design, manufacture, and operation of the machinery and equipment used to improve petroleum drilling, and the processing of petroleum or chemical products.

Environment

In the United States, we use more petroleum than any other energy source. Petroleum products—gasoline, fertilizers, plastics, and medicines—have brought untold benefits to Americans and the rest of the world. We depend on these products, and, as consumers, we demand them. However, these benefits are not without cost. Petroleum production, distribution, and combustion can also contribute to air and water pollution.

Drilling for, transporting, and improper disposal of petroleum can endanger wildlife and damage the environment. Leaking underground storage tanks can pollute groundwater and create noxious fumes. Processing petroleum at the refinery can contribute to air and water pollution. Burning gasoline and diesel to fuel our cars and other small engines such as lawn mowers contributes to air pollution. Even waste petroleum drained from the family car, if not properly recycled, can pollute rivers and lakes.

Many advances have been made in protecting the environment since the passage of the Clean Air Act in 1970. Petroleum companies have redesigned their refineries to reduce emissions into the air and water. Gasoline mixtures have been reformulated to burn cleaner, dramatically cutting the levels of nitrogen oxide, carbon monoxide, and hydrocarbons released into the air. Removing lead from gasoline has significantly reduced the amount of lead pollution in the last 40 years.

Like petroleum, burning natural gas releases pollutants into the atmosphere when burned. However, natural gas is the least polluting fossil fuel. Burning natural gas produces less sulfur, carbon, and nitrogen than burning petroleum or coal. Natural gas also emits little ash particulate into the air when it is burned.

The production, transportation, distribution, and combustion of petroleum and natural gas are strictly regulated to minimize the negative effects on the environment and people. Our dependence on petroleum presents a continuing challenge. In the future we must balance the demand for petroleum products with protection of the global environment.

OSEBERG FIELD CENTER—PETROLEUM

Photo Courtesy of Harald Petterson

AIR POLLUTION

Petroleum fuels can contribute to air pollution.

Future

Petroleum and natural gas are nonrenewable resources. Because one day they will run out, we need to begin transitioning toward renewable, sustainable supplies of energy. In addition, new technologies will be necessary to improve the way that petroleum and natural gas are utilized and extracted. Developments in materials science, engineering, drilling, nanotechnology, and other research areas will continue to improve the extraction techniques and use of petroleum and natural gas.

One such technique already in use is horizontal drilling, which the petroleum industry has used for many years to increase production and minimize the environmental impact of drilling multiple vertical wells. The natural gas industry is now using horizontal drilling to more widely access reserves.

In horizontal drilling, a vertical well is drilled to the formation that has been identified as a reservoir. Then the drill bit can be turned up to a 90 degree angle so that the well parallels the reservoir. This allows the maximum amount of petroleum or natural gas to be recovered.

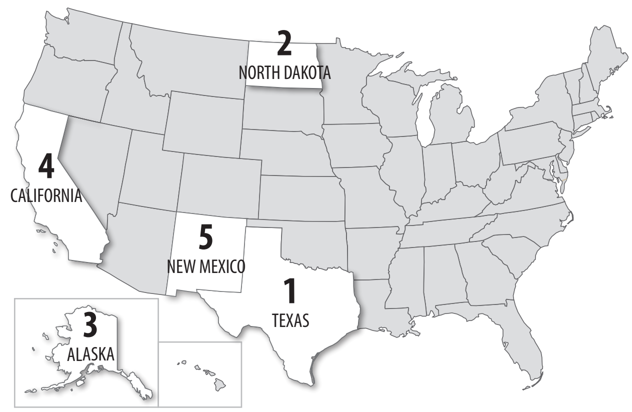
The Energy Information Administration estimates that at the current rate of consumption there are enough natural gas reserves to last about 90 years. Shale gas is a major component of the known reserves. Advances in horizontal drilling and hydraulic fracturing have made production of natural gas from **shale plays**, formations containing significant accumulations of natural gas, economical. The Annual Energy Outlook projects that by 2035, production of shale gas will make up 45 percent of the U.S. natural gas supply.

There are rich deposits of petroleum and natural gas on the outer continental shelf (OCS), especially off the Pacific coasts of California and Alaska, in the Gulf of Mexico, and in certain basins off the Atlantic coast. Thirty basins have been identified that could contain enormous petroleum and natural gas reserves. It is estimated that 30 percent of undiscovered U.S. natural gas and petroleum reserves are contained in the OCS. Beyond these domestic possibilities, there are also many untapped deposits around the world that other countries could develop.

Lease sales are the process by which the U.S. Department of the Interior grants permission to use offshore land. Any development of resources may only occur on previously open lands. No drilling is currently permitted on the entire Pacific Coast, Atlantic Coast, Eastern Gulf of Mexico, and parts of Alaska; however, the current government administration is working on a new program that may include these areas.

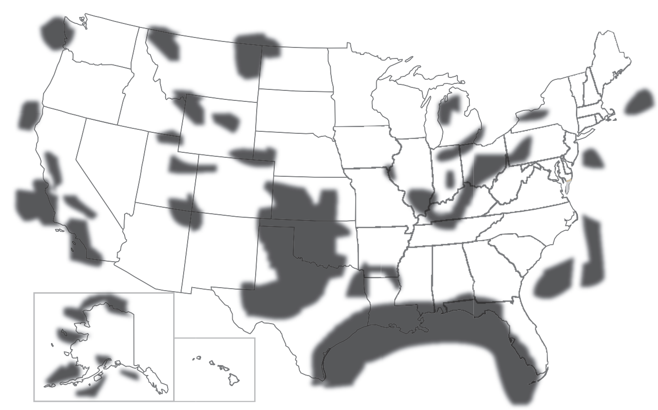
Some other areas of potential development that could affect natural gas production and distribution include methane hydrates, biomass, and liquefied natural gas. Scientists continue to research new ways to obtain natural (methane) gas from biomass—a fuel source derived from plant and animal wastes. Methane gas is naturally produced whenever organic matter decays. Today, we can drill shallow wells into landfills to recover the methane gas. Landfills are already required to collect methane gas as a safety measure. Typically, landfills collect the gas and burn it to get rid of it; but the gas can be put to work. In 2017, landfill gas generated 11.5 billion kilowatt-hours of electricity. There are other ways to convert biomass into natural gas. One method uses aquatic plants, such as sea kelp, to produce methane gas. In the future, huge kelp farms could produce a renewable source of gas.

Top Petroleum Producing States, 2017



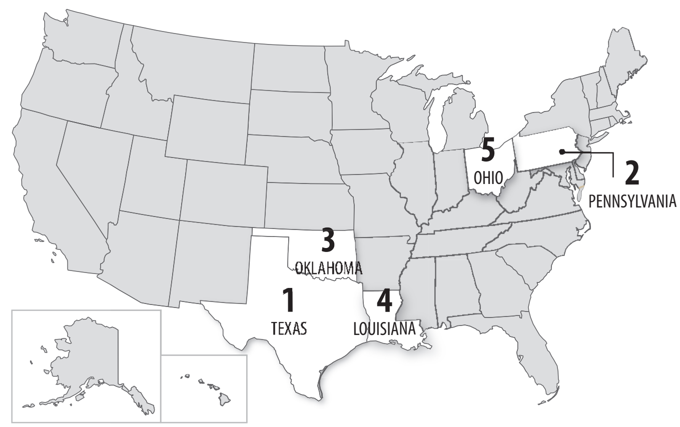
Data: Energy Information Administration

Oil and Natural Gas Basins



Data: Energy Information Administration

Top Natural Gas Producing States, 2017



Data: Energy Information Administration

As the demand for petroleum and natural gas grows and the issues become more and more complex, energy companies are using advanced technologies to design and deliver next generation fuels and products. The skills used by all workers in the petroleum and natural gas industries are transferable to these new technologies. New opportunities are emerging every day.

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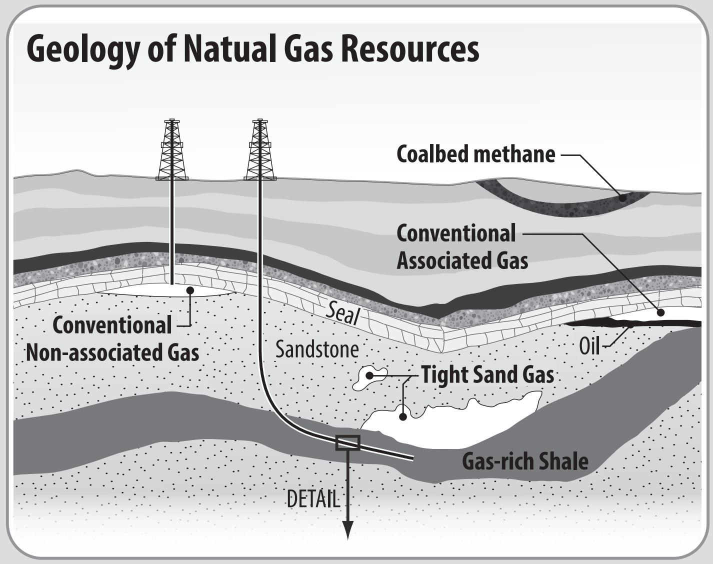
What is Hydraulic Fracturing?

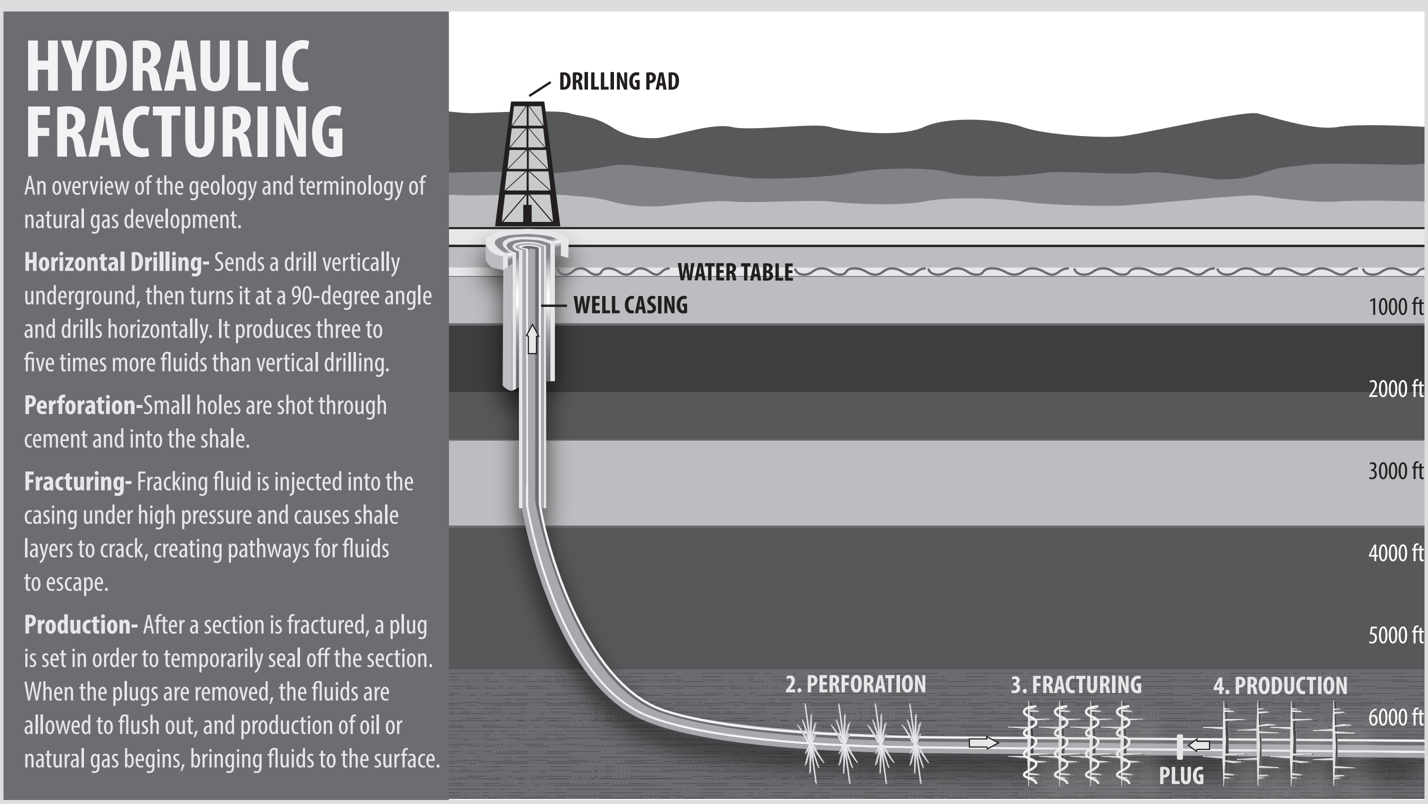
Consumers can make a real difference by recycling petroleum–based products and buying products that conserve energy.

We know that oil and natural gas are trapped in porous rocks far beneath the surface of the Earth. People have been taking advantage of oil and gas that make their way to the surface on their own for hundreds of years. But if gas and oil are trapped beneath the Earth's surface, how have people been able to use it without drilling for it? How did that gas even get to the surface in the first place?

The surface of the Earth is a lot like swim rafts floating on top of a swimming pool. The rocky "rafts," called plates, move and shift around, and bump into each other. Sometimes the bumping is strong, and results in an earthquake. Sometimes the shifting is slight, and barely noticeable to all but the most sensitive of equipment. Slight shifts cause cracks in the rocks, and it is through these fractures in the crust that oil and gas can escape. This is what causes the bubbles of oil and natural gas to rise from the floor of the ocean – it's merely small amounts of oil and natural gas rising from small fractures in the rocks of the ocean floor.

Because not all oil and gas deposits are as easy to reach as drilling a hole and pumping the oil or gas to the surface, other methods are needed. Geologists looking for ways of extracting oil and gas first look for natural fractures from which fluids are already escaping. These are good places to use hydraulic fracturing to get the oil and natural gas out of the ground. **Hydraulic fracturing**, or "fracking," is a means of using pressurized solutions of water, sand, and small amounts of other substances (like detergents) to crack, or fracture, shale, and allow easier extraction of the oil or gas locked inside.





Developed in the 1940s, fracking has been perfected and combined with horizontal drilling technology to reach previously unattainable oil and natural gas deposits.

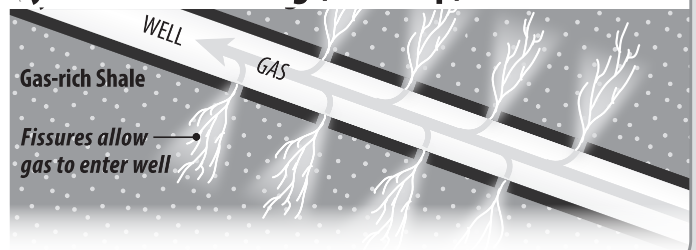
The first step in fracking begins as any other oil or natural gas well begins—with a vertical drill penetrating the layers of dirt and rock beneath the surface. A thick fluid, called mud, is pumped down to the drill to help keep it cool and lubricated. Rock fragments and soil are removed when the mud is circulated. Once the boring motor has reached a depth well below the groundwater aquifer, several thousand feet below the surface, a surface casing made of steel is inserted in the hole, and cement is pumped down into the casing and pressurized so it flows upward around the outside of the pipe. This process is repeated several times to create several barriers, at different depths around the pipe.

When the cement has hardened, a special drilling motor is re-inserted into the casing, which drills through the bottom of the cement and continues down toward the shale formation. The special drill used in this part of the recovery process can drill at an angle, so that a curving hole is made in the ground, eventually becoming horizontal at the appropriate location within the shale formation.

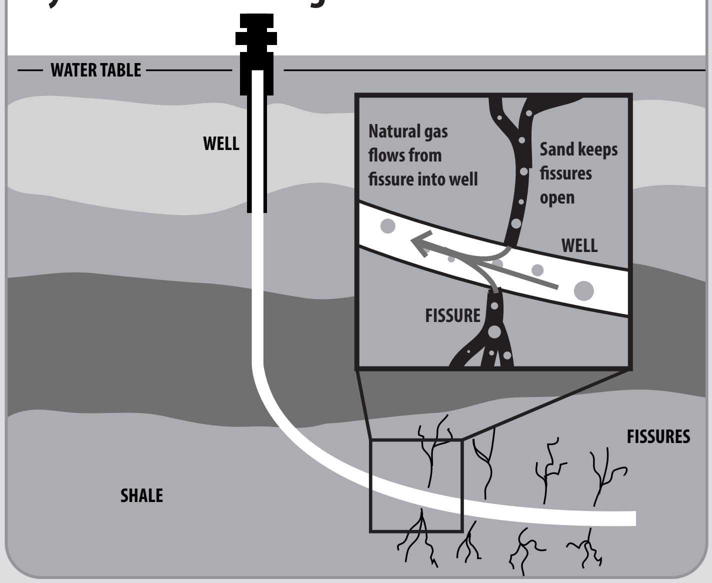
At this point, the drilling motor is removed, and a casing is inserted into the horizontal hole. A device loaded with explosive charges is inserted into the casing. When the charges are detonated, small holes are blown into the casing, perforating it. Hydraulic fluid containing a mixture of mostly water and sand, and a small amount of other substances, is pumped under high pressure into the perforated casing and out into the shale. The high pressure liquid causes the shale to fracture, and when the water drains, the sand remains, holding the fractures in the shale open. Previously trapped natural gas can now seep through the fractures and into the casing through the perforations. The casing is plugged behind the perforations, and the perforation and fracturing processes are repeated, plugging after each fracture. When the entire casing has been perforated and the adjacent shale is fractured, the plugs are drilled away, and the oil or natural gas can flow freely through the shale fractures into the perforated casing and out to the well.

Advancements in drilling and fracturing techniques have made the extraction of shale gas possible to meet increasing demand for natural gas. Development of natural gas from shale plays using hydraulic fracturing presents some challenges, including the need for access to water for use in the process and the need to protect local drinking water and other natural resources, and transportation concerns in order to move the natural gas to industry and consumers. In some areas, development of shale gas brings drilling operations closer to local residential communities too, making land and homeowner cooperation and collaboration a high priority for companies engaged in development of these resources. Different states have different regulations regarding the mineral rights, processes, and taxes. Companies need to balance these concerns while protecting the environment and the resource.

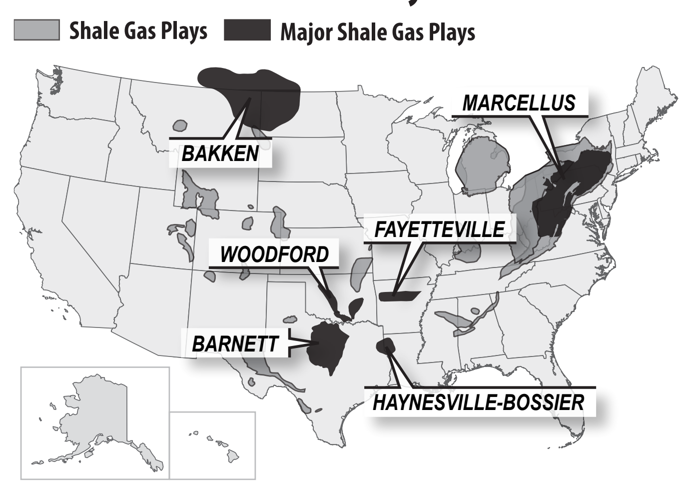
Hydraulic Fracturing (Close-up)



Hydraulic Fracturing



Location of Shale Gas Plays



Data: Energy Information Administration

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FORMATION ACTIVITY

Formation of Petroleum and Natural Gas

Scene One

570 million years ago—during a period known as the "Paleozoic Era" [paley-uh-zo-ik]—a large sea covered the area we now recognize as the southern part of the United States. In this sea lived a vast number of microscopic plants and animals called plankton. This microscopic plankton drifted on or near the surface of the water and became so numerous that it could actually be seen with the naked eye. Throughout the Paleozoic Era the sea was also alive with trilobites, corals, crinoids, brachiopods, and many other plants and animals that evolved over millions of years. A trilobite was a strange-looking little creature. Small grooves divided its body and hard-segmented shell into three vertical parts. A semicircular shield covered its head. Coral, which still exists today, came in many different sizes, shapes, and colors. The coral polyps were simple animals that were able to take calcium out of saltwater and convert it into a rock-like shelter in which they lived. Crinoids anchored themselves to rocks on the sea floor with a root-like structure that supported a stalk or column topped by a cup-like cavity, which formed a protective case for a flower. Brachiopods were clam-like animals. Their two-piece dorsal and ventral shells enclosed and protected their soft body parts. Due to their ability to reproduce quickly, the plankton, along with other sea life, were abundant. As these carbon-containing organisms went through their extremely short life cycles and died, their remains sank to the deep sea floor and became covered with the mud, sand, and sediment from the eroding mountains and surrounding areas. Because they were buried so quickly on the deep sea floor, the plankton and other sea creatures lacked oxygen, which is necessary for decay or decomposition. Draw a picture that shows this scene on the first section of your paper.

Scene Two

320 million years passed, and layers of sediment on the sea floor became thousands upon thousands of feet deep. These layers were filled with dead plankton, fossilized sea creatures, and eroded rock. During the time period known as the "Mesozoic Era" [mez-uh-zo-ik], dinosaurs began to roam the Earth and swim in the sea. More than half of the great sea had disappeared because of evaporation, earthquakes, and the filling and layering of sediments on the sea floor. This heat and pressure was responsible for changing the dead organic material into hydrocarbons (substances containing hydrogen and carbon) and causing the remaining inorganic material to change into sedimentary rock. Draw a picture that shows this scene on the second section of your paper.

Scene Three

250 million years later brings us to present day—the "Cenozoic Era" [sen-uh-zo-ik]. People now walk the Earth and the dinosaurs have long since disappeared. Erosion and other sediments have now completely filled the ancient seas. The heat and pressure have formed many layers of sedimentary rock, and deep source rock—rock where oil and natural gas form. Much of the water that was in the sea is now in the pore spaces of the sedimentary rock. The remaining water evaporated or was pushed into areas where seas or oceans now exist. Over millions of years, temperatures ranging from 150-300 degrees Fahrenheit (66-149 degrees Celsius) have "cooked" the organic materials causing a complex chemical change, creating hydrocarbons called oil and natural gas. These hydrocarbons, also known as fossil fuels, have been discovered in many parts of the country and all over the world. Texas produces the most of these fuels. Can you picture this scene? Draw a picture that shows this scene on the third section of your paper.

As you finish the last scene, keep in mind that there are several theories concerning the formation of oil and natural gas. What you have just heard and drawn is the most widely accepted scientific theory.

Chemical Models

Background

Hydrocarbons are molecules composed only of carbon and hydrogen. Carbon atoms have four electrons available to bond. When one carbon atom bonds with only hydrogen, it will need four hydrogen atoms. This hydrocarbon is known as methane.

When a hydrocarbon molecule has as many hydrogen atoms bonded as possible, it is considered saturated with hydrogen and is part of the alkane group. Alkanes are named for the number of carbon atoms present in the longest carbon atom chain. Simple, alkanes are a straight chain of carbon atoms saturated with hydrogen.

The generic formula for alkanes is C_nH_{2n+2}. This formula can be used to determine the molecular formula for the gases that typically compose raw natural gas.

Naming hydrocarbons involves using the appropriate root to indicate the number of carbon atoms in the longest carbon chain. Alkanes have the suffix ending -ane. Thus, a root plus -ane form the name of a simple, saturated hydrocarbon.

Hydrocarbon Series Roots

Number of Carbons	Root
1	*meth-*
2	*eth-*
3	*prop-*
4	*but-*
5	*pent-*
6	*hex-*
7	*hept-*
8	*oct-*
9	*non-*
10	*dec-*

Activity 1: Molecular Formulas

Use the generic formula for alkanes to determine the molecular formula for the following simple alkanes:

Methane

Ethane

Propane

Butane

Pentane

Hexane

Heptane

Octane

Nonane

Decane

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Activity 2: Molecular Models

Use the molecular model sets or modeling clay to make three-dimensional models of the alkanes. Use one color to represent hydrogen and another for carbon. Use the third color to make several oxygen molecules, which consist of two oxygen atoms bonded together (O_2). Draw each model below.

Methane	***Ethane***
Propane	***Butane***
Octane	***Oxygen***

Activity 3: Balancing Equations

When a hydrocarbon burns, it combines with oxygen to make carbon dioxide and water. Fill in the molecular formula for each compound and then write the balanced equations for methane, propane, butane, and octane.

Methane

$\_\_\_\_\_\_ + O_2 \xrightarrow{HEAT} CO_2 + H_2O$

Propane

$\_\_\_\_\_\_ + O_2 \xrightarrow{HEAT} CO_2 + H_2O$

Butane

$\_\_\_\_\_\_ + O_2 \xrightarrow{HEAT} CO_2 + H_2O$

Octane

$\_\_\_\_\_\_ + O_2 \xrightarrow{HEAT} CO_2 + H_2O$

Activity 4: Hydrocarbon Combustion

Using the chemical models of methane and oxygen, create the products of methane combustion. Draw all the model molecules formed for a balanced reaction.

Repeat the process for propane. For an added challenge, if time allows, try drawing the combustion of octane.

COMPOSITION ACTIVITY

Hydrocarbon Properties

Question

What properties make a compound useful for a transportation fuel?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- Graph paper or computer
- Table of Physical Properties below

✔ Procedure

1. The table shows some physical properties of hydrocarbons with differing numbers of carbon.
2. Graph the melting and boiling points vs. the number of carbons in the molecule. You can do this by hand, or on a computer. Do not connect the data points, and graph both sets of data on the same set of axes. Make sure you properly label your graph and indicate a legend for the plot.
3. Graph the heat of combustion vs. hydrocarbon size on a different chart for all applicable hydrocarbons. Make sure you properly label all parts of your graph.

Physical Properties of Hydrocarbons

Hydrocarbon Name	Number of Carbons	Melting Point (°C)	Boiling Point (°C)	Heat of Combustion (kg cal)
methane	1	-182	-164	212.79
ethane	2	-183.3	-88.6	372.81
propane	3	-189	-42.1	530.57
butane	4	-139.4	-0.5	
pentane	5	-130.0	36.1	845.16
hexane	6	-95.0	69.0	995.01
heptane	7	-90.6	98.4	1149.90
octane	8	-53.8	125.7	1302.70
nonane	9	-51.0	150.8	
decane	10	-29.7	174.1	1610.20
undecane	11	-25.6	196.0	
dodecane	12	-9.6	216.3	
tridecane	13	-5.5	235.4	
tetradecane	14	5.9	253.7	
pentadecane	15	10.0	276.0	
hexadecane	16	18.2	284.0	2559.10
heptadecane	17	22.0	301.8	
octadecane	18	28.2	316.1	
nonadecane	19	32.1	329.7	
eicosane	20	36.8	343.0	3183.10
heneicosane	21	40.5	356.5	
docosane	22	44.4	368.6	
tricosane	23	47.6	380.0	
tetracosane	24	54.0	391.3	
pentacosane	25		401.9	

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⁂ Analysis and Conclusions

1. Using the melting point/boiling point graph, draw a light pencil line across the graph at approximately -10°C. Draw another line across the graph at about 40°C. This indicates the minimum and maximum temperatures for most of the United States year-round. Lightly shade in the area of the graph between the two lines. Where is room temperature on this graph?

2. Explain the general trend you observe in your melting point/boiling point graph.

3. Looking at your melting point/boiling point graph, match up the melting point and boiling point of each hydrocarbon by drawing a vertical line from the melting point to the corresponding boiling point.

4. Which items do not fall in the average temperature range for melting or boiling? What state of matter do you think the items must be if their melting and boiling point are very low (under the average temperature range)? What state of matter must they be if both are high (above the average temperature range)? What state of matter might they be if at least one of their points falls within the average range?

5. Why might boiling point and melting point be important for hydrocarbons? (Hint, look at the names of the items on your data table)

6. Look at your heat of combustion graph. Heat of combustion is the amount of energy that is obtained by burning a molecule. What is the general trend you observe on this graph?

7. Using your graphs and the *Fractional Distillation* graphic on page 55 of the informational text, label your heat of combustion graph to show where propane, gasoline, jet fuel, and diesel might be found within the data. Use your graphs and the graphic on page 55 to explain why these fuels might be used the way they are.

COMPOSITION ACTIVITY

Exploring Polarity

Background

Polarity is a physical property that describes whether or not a substance contains polar molecules. A polar molecule has bonded in a way that has an uneven distribution of electrons, creating an electric field or charged ends. Polarity determines how well substances mix. Polar substances dissolve in other polar substances, while nonpolar substances dissolve in nonpolar substances.

Question

How do polar and nonpolar substances interact when mixed together?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- 2 Foam and 2 biodegradable starch packing peanuts
- Acetone
- 2 100 mL Beakers
- 2 Stirring rods
- Safety goggles
- Water

Procedure

1. Obtain two packing peanuts labeled "A" and two labeled "B" from the instructor.
2. Record at least three different properties for each type of packing peanut.
3. Fill a 100 mL beaker with 50 mL of water and a second 100 mL beaker with 50 mL of acetone.
4. Put one "A" packing peanut into each beaker and stir.
5. Record whether the peanuts dissolve in acetone or water.
6. Put one "B" packing peanut into each beaker and stir.
7. Record whether the "B" peanuts dissolve in acetone or water.
8. Clean up according to your teacher's instructions and answer the questions.

Data and Observations

Packing Peanut Type	Action in Acetone	Action in Water
A		
B		

Analysis and Conclusions

1. Which solvent is polar? ___________________ Which solvent is nonpolar? _____________How do you know?

2. Based on your observations, which peanut, A or B, is polar? How do you know?

3. Based on your observations, which peanut, A or B, is nonpolar? How do you know?

4. Ask the teacher for the identity of the materials from which the peanuts were made. The polar substance is ________________________ and the nonpolar substance is _________________.

5. Gasoline is made from refined petroleum, like many hydrocarbons, and is nonpolar. What would happen if it was transported in a styrofoam™ container? Explain why this is important.

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FORMATION ACTIVITY

Fault Blocks

Questions

What happens when the tectonic plates of the Earth move and push against each other? How does oil and gas get trapped beneath rock layers?

Hypothesis

Draft a hypothesis to answer the questions using an "If...then...because..." format.

Materials

- Wooden block that is 8" x 3" x 1" cut in three pieces
- Candle or paraffin wax
- Markers or crayons
- Ruler
- Sandpaper
- Permanent markers
- White paper

Procedure

1. Stand the 3 blocks up on the most narrow edge.
2. Gently push inward on the outer two blocks toward the center block.
3. Pull the outer two blocks outward away from the center block.
4. Record observations about the way the layers shift to show faults.
5. Cut a white piece of paper in a dome shape and tape it to the center block to show a salt dome.
6. Push the two outer blocks toward the center block forcing the salt dome upward.

Conclusions

1. How do the wooden blocks show what happens in the Earth's crust?

2. Describe how the wooden blocks demonstrate the way mountains are formed.

3. Explain how the wooden blocks model the formation of a salt dome.

FORMATION AND EXPLORATION ACTIVITY

Mapping the Ocean Floor

Background

The Earth's crust is divided into plates; layers of rock that are slowly and constantly moving. These plates meet at areas called plate boundaries. There are three types of boundaries:

- convergent—where plates push towards each other
- divergent—where plates spread apart from each other
- transform—where plates slide past each other

Question

How does the age of the rocks help geologists find oil and natural gas?

Hypothesis

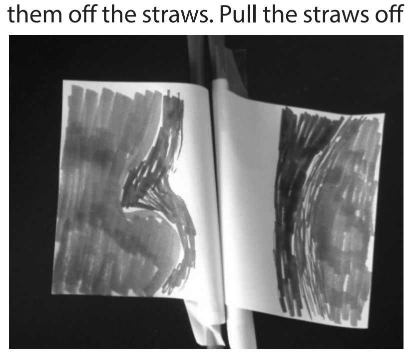
Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- 2 Large smoothie-sized straws
- White paper
- Scissors
- Tape
- Markers of several different colors

Procedure

1. Cut a piece of white paper in half lengthwise.
2. At one end of both pieces of paper, use green and brown markers to draw a land mass.
3. Use a light blue marker to draw the shallow portion of ocean along the land mass. It should somewhat resemble the coast of the land mass in shape, but does not have to be identical.
4. Starting at one of the uncolored ends, wind one piece of paper onto one straw. It's not necessary to make it perfectly straight. Secure it lightly to the straw with a piece of tape.
5. Tape the ends of the straw down tight to your desk or table top.
6. Repeat step 4 for the other piece of paper.
7. Tape the second straw down closely beside the other, so the end of the paper is opposite the first (see diagram).
8. Use a marker to draw down the small crack between the pieces of paper. Make sure the line is on both pieces of paper.
9. Remove the piece of tape holding the straw and paper together. If possible, leave it attached to the paper.
10. Pull both pieces of paper out from the center, the same amount for each.
11. Use a marker of a different color to draw down the small crack between the pieces of paper.
12. Repeat steps 9-11 until you have pulled the papers completely apart from each other. Vary the amount that you pull the papers apart. Sometimes, pull them out just a little bit, and other times pull them apart quite a bit.
13. When you have drawn lines on and completely pulled both pieces of paper out all the way, pull them off the straws. Pull the straws off your desk and discard or set aside.



14. Fold both pieces of paper over at the last line you drew.
15. Tape the pieces of paper together on the back side, keeping the folded edges together like a seam between two pieces of fabric being sewn.
16. Turn the paper over, and fill in the spaces with the appropriate colored marker so the paper is completely colored in. You will have blocks of color that follow the same order from center to outer edges.
17. Answer the questions about your "ocean floor map."

⁂ Conclusions

1. Each sheet of paper represents an ocean plate. The space between them represents the boundary between the two plates. The green land masses represent two continents that are separated by the ocean. In this activity, the ocean plates are moving away from each other and each color block represents the same amount of time, regardless of how wide or narrow they are. Which type of zone (convergent, divergent, or transform) does this model represent? How do you know?

2. What color on your paper represents the oldest rocks?

3. What color on your paper represents the newest rocks?

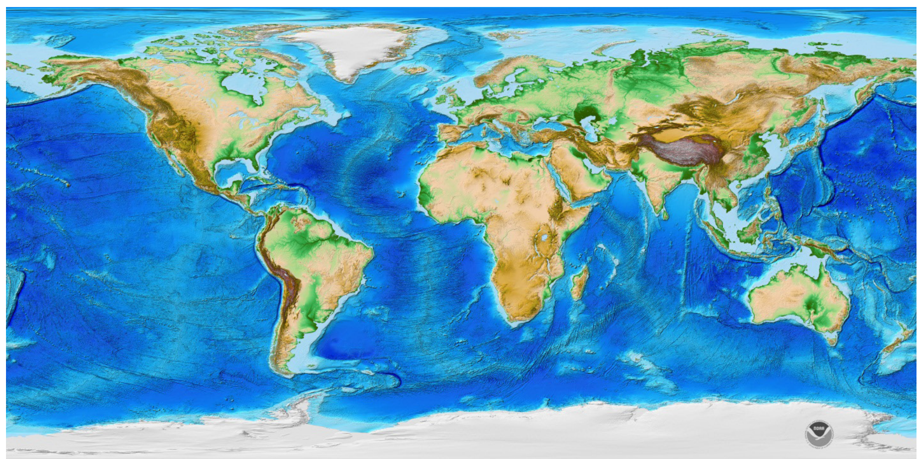
4. What color on your paper shows a time of the most movement of the plates?

5. What color on your paper shows a time of the least movement of the plates?

The image to the right from NOAA, made by compiling data produced by bathymetry of the ocean floor, shows the contours and the depth of the ocean. The lighter shades indicate shallower water, while the darkest shades indicate the deepest water.

Note that the middle of the northern Atlantic Ocean is relatively shallow as compared to the rest of the ocean. This is the boundary between the two plates that make up the northern Atlantic Ocean floor.

The image below is a combination of two NOAA maps and shows the age of rocks on the floor of the northern Atlantic Ocean.



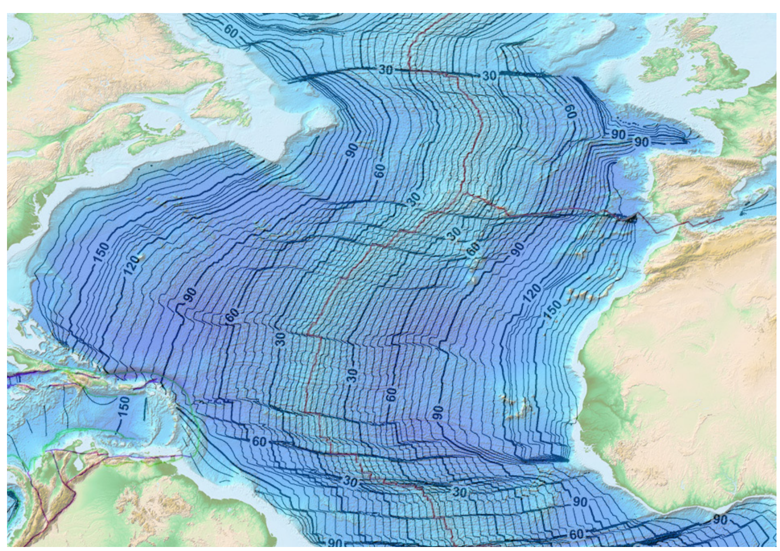
NOAA bathymetry map

Each line marks a fixed amount of time passing. The numbers show the age of the rocks in millions of years. Scientists used radioisotope dating to determine the ages of the rocks. Younger rocks will have a higher concentration of radioactive isotopes in them, and older rocks will have less radioactive elements because they have had more time to decay. Therefore, the proportion of radioactive elements will be higher in younger rocks. Because of the nature of radioisotope dating, the age of younger rocks is more certain than the older rocks.

Using what you have learned about the spreading of the sea floor, and the age of the rocks, use the topographical map above to answer the following questions:

6. Where would you expect to find the oldest rocks: along the ridge in the middle where it's shallower; or at the deeper parts of the ocean?
7. Would you expect to find oil and natural gas deposits beneath older or younger rocks?
8. If you were employed to search for petroleum and natural gas in the ocean, what is one place in the Northern Atlantic Ocean where you would start looking? Explain your answer in at least two sentences.

Staple your colored paper model to this assignment or in your science notebook for reference.



NOAA age combo map

EXPLORATION ACTIVITY

Exploring Sound Waves

Question

How do sound waves travel?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- Metal slinky spring
- Large foam cup
- Small foam cup

Procedure *LONGITUDINAL WAVES*

1. Place the slinky on the floor so the coils are all together facing up. Place the large foam cup inside of the slinky coils and press in gently.
2. Lift the cup straight up. The end coils should come up around the center of the cup.
3. Place your hand around a few coils in the cup's middle to hold the slinky in place.
4. Bounce your hand up and down to create longitudinal waves and observe the sound vibrations echoing from the cup.
5. Repeat your hand motions at different heights—low and high—to hear the different sound vibrations and see the longitudinal waves produced.
6. Remove the large cup and repeat the investigation with the small cup.

Conclusions

1. Was there a difference in longitudinal waves produced from the trials at different heights? Describe.

2. What was the difference in the two sounds you heard from the two different cups?

3. Sound waves and seismic waves are both longitudinal waves. Explain how you think seismic technology might be helpful to locate specific geologic formations underground.

EXPLORATION ACTIVITY

Exploring Core Sampling

Question

Are all core samples the same?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- 4 Colors of sand
- 1 Clear plastic straw per student
- 1 Opaque cup per student
- Water in a spray bottle
- Plastic spoons
- Ruler
- Additional sand or gravel (optional)

NOTE: When layering earth materials in cups, you can arrange the layers in any order.

✔ Procedure

1. Place a layer of one of the earth materials in the cup with a spoon. Use the ruler to make sure the layer is at least 1 cm deep. Mist with the spray bottle of water until damp, but not soaking.
2. Place another earth material on top of the first layer "it can be thicker than 1 cm". Mist with water until damp.
3. Continue alternating layers of earth materials and water. The total height of the layers stacked in the cup should be at least 4 cm deep.
4. Trade cups with someone else so you are not pulling a core sample from your own cup.
5. Use a straw to extract a core sample by pushing the straw straight down through the layers in the cup.
6. Place your finger tightly over the top end of the straw and withdraw it from the cup. Observe the layers in the straw core sample.
7. Lay several core samples from different cups side by side. Compare results.

Conclusions

1. What are core samples?

2. Did you encounter any challenges when pulling up your core sample? If so, what was the challenge? How does this relate to real world drilling?

3. What are petroleum geologists looking for when they examine core samples?

4. What about your core sample might be similar or different from an actual core sample?

EXPLORATION AND PRODUCTION ACTIVITY

Exploring Porosity

Questions

Which size gravel will have the greatest porosity? Why is this?

Hypothesis

Draft a hypothesis to answer the questions using an "If...then...because..." format.

Materials

- 350 cm^3 Large rocks
- 350 cm^3 Medium rocks
- 350 cm^3 Small rocks
- Water (can be dyed with food coloring to enhance activity)
- 3 600 mL Beakers
- 100 mL Graduated cylinder

✔ Procedure

1. Fill one beaker to the 350 cm^3 mark with the large rocks. Fill the second beaker with 350 cm^3 of medium rocks. Lastly, fill the third beaker with 350 cm^3 of small rocks (Remember, one cm^3 is equal to one mL).
2. Fill the graduated cylinder with 100 mL of water.
3. Slowly pour water into the first beaker until the water reaches the top of the rocks. Record exactly how much water you poured into the beaker. If you need more than 100 mL of water, fill the graduated cylinder again.
4. Follow Step 3 again for the other two beakers filled with rocks.
5. Calculate the porosity of the three materials using this formula:

$$\text{Porosity} = \frac{\text{Volume of Water}}{\text{Volume of Material}} \times 100$$

TYPE OF MATERIAL	VOLUME (mL) OF WATER POURED	VOLUME (cm^3) OF MATERIAL	PERCENTAGE OF PORE SPACE IN MATERIAL
Large rocks			
Medium rocks			
Small rocks			

Conclusions

1. Which size of rocks has the greatest porosity? Explain why.

2. Explain porosity's importance in determining the best location for an oil well.

PRODUCTION ACTIVITY

Getting the Oil Out

Activity courtesy of SPE

Background

Artificial lifting systems, or pumping units, are used to help pull the oil out of the reservoir rock and pump it up the well. A down hole pump in the well is connected to the pumping unit by steel rods, which are screwed together. The pump is activated from the up and down movement of the pumping unit on the surface. As the pump plunges down, fluid from the rock formation flows into the pump chamber. On the upstroke, the fluid in the chamber is forced up the tubing, to the surface.

Question

Will it be easier to bring up liquid with a long tubing system, or a short tubing system?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials *FOR EACH STUDENT OR PAIR*

- 8-10 Drinking straws
- Masking tape
- Scissors
- Ruler
- Carton of chocolate milk or dark-colored, low viscosity beverage (that can be seen through the straw)
- Paper towels

✔ Procedure

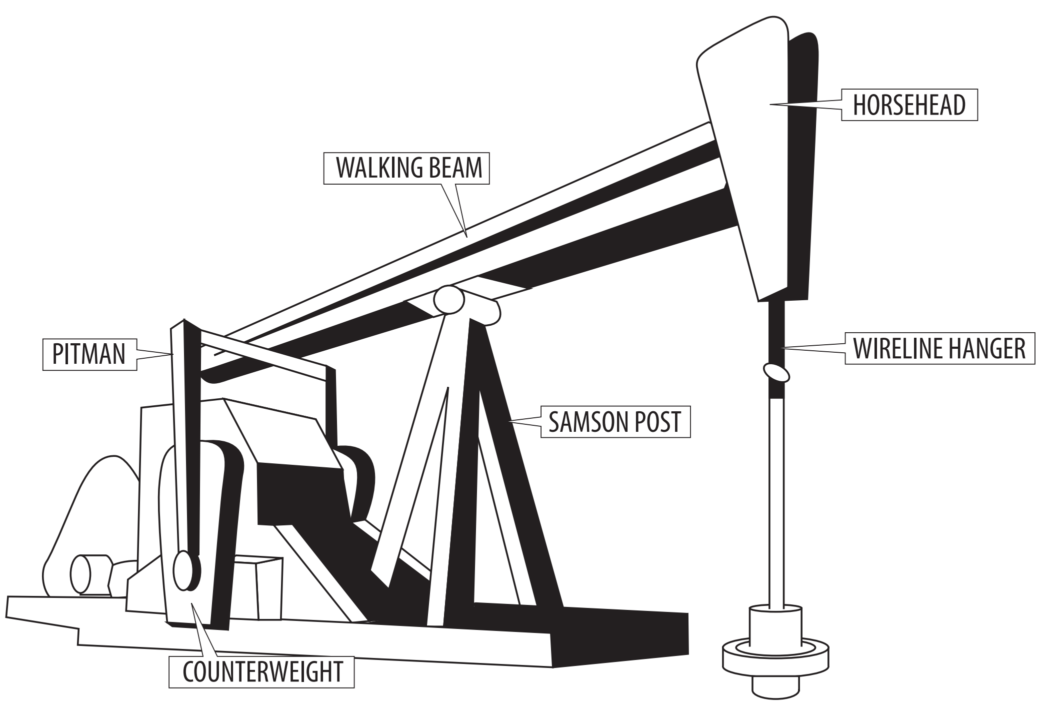
1. Using the scissors, cut a 1 cm slit at one end of each straw.
2. Join the straws end to end to form one long tube. Place the slit end of the straw into the inside of the adjoining straw.
3. Place masking tape over each connected end to secure the joint and create an air tight seal.
4. Place beverage on the floor. One member of the group stands up and inserts the extended straw "tubing" into the beverage trying to bring the liquid to the top of the "tubing" using his/her suction.
5. Now, decrease the number of straws used for the "tubing" by cutting off one straw. The same student tries to bring the liquid to the top.
6. Continue cutting off one straw at a time. After each cut try to bring the liquid to the top of the tubing.

Conclusions

1. Which length of straw required the most effort to bring the liquid to the top? Which length of straw required the least effort to bring the liquid to the top? Explain why.

Extensions

- Try to pull up liquids of different viscosities and densities.
- Try using straws of different diameters to make your tubing.
- Study the diagram of the artificial lift system. Use the diagram to estimate how the system works to retrieve oil. Record your thoughts in your notebook. Using the *Oil and Natural Gas* book by the Society of Petroleum Engineers, or internet sources, research how a horsehead pump actually works.



PRODUCTION ACTIVITY

Perforated Well Casing

Question

How do you think adding holes to a well casing will influence the amount of petroleum or natural gas that a well can produce?

Hypothesis

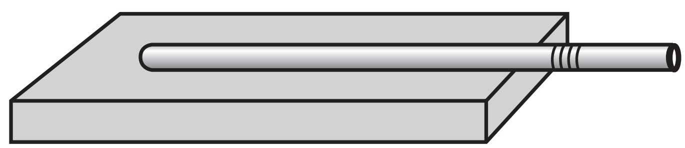
Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- 2 Kitchen sponges, the same size and shape
- Flexible straws
- Push pin
- Shallow tray (for sponges)
- Shallow tray (for collection from straw)
- Plastic wrap
- 1-3 Heavy books or weights
- 10-25 mL Graduated cylinder
- Water
- Tape
- Paper towels

✔ Procedure

1. Lay plastic wrap out across your shallow tray. Place one sponge on top of the plastic wrap.
2. Lay a straw on the sponge so the bottom edge of the straw is inside the end of the sponge and the elbow end of the straw stretches out beyond the edge of the sponge. If necessary, trim the bottom end of the straw so the end of it is inside the end of the sponge by at least 3 cm (see diagram).



3. Lay the second sponge on top of the straw/sponge combination so the edges align with the first sponge.
4. Pour water on the sponges so they are saturated but almost no water is leaking out. Record how much water you used.
5. Wrap the plastic wrap around the sponges and up around the straw, trying to create a sealed set-up with no places for water to leak out. Use tape if necessary to help create a seal. Make notes of your assembly so you can repeat the set-up again.
6. Place the other shallow dish beneath the end of the straw protruding from the sponges.
7. Gently lay a heavy book on top of the sponges and observe the amount of water that comes from the straw.
8. Add another book to the first, and continue until no water comes from the straw. Try using your arms to provide more pressure, if needed.
9. Record observations. Measure the amount of water in the collecting dish by pouring it into the graduated cylinder.
10. Disassemble the stack of books, sponges, and straw. Drain or squeeze your sponges to remove as much remaining water as possible.
11. Using a push pin, poke several holes about 3-5 mm apart on both sides of the end of the straw that was between the sponges. (If straws are striped, use the stripes as a guide).
12. Replace the straw in the stack of sponges. You will likely require a new piece of plastic wrap before saturating the sponges.
13. Repeat steps 4-8 using the same amount of water as in step 4, and duplicate your assembly as closely as possible.
14. Record observations.

Data

Condition of Straw	Amount of Water to Start	Amount of Water Collected
Solid (no holes)		
Perforated (with holes)		

Observations

Conclusions

1. How did perforating (poking holes in) the straw change the amount of water you collected?

2. Using your observations, explain how perforating a well casing would be beneficial in a drilling scenario.

3. How could you improve this model?

Extension

- Re-design the model based on your suggested improvements, or using different materials like sealable plastic bags, tape, etc.

PRODUCTION ACTIVITY

Visualizing Hydraulic Fracturing

Question

How does hydraulic fracturing create channels in shale for natural gas and oil to be removed?

Hypothesis

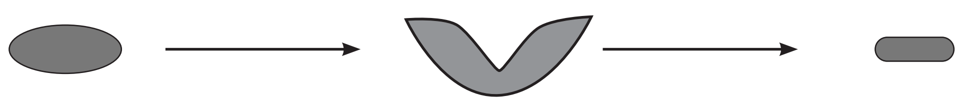
Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- 140 mL Syringe
- Extra-large straw
- Fracking box
- Packing tape
- Plastic wrap
- Paper towels
- Hydrated gel beads
- 125 mL Breakfast syrup
- Push pin or tack
- Ruler
- Water
- Cup

✔ Procedure

1. Place a layer of paper towels under the fracking box.
2. Fill the fracking box with hydrated gel beads so that the beads fit together snugly and the lid of the box slides closed easily. Observe the layout of the beads and draw a picture of your observations in "Box 1" on the following page. (Hint: It may be beneficial to strain the beads before filling the box.)
3. Line up the straw on top of the ruler. Starting about 4 cm from one end of the straw, poke a total of 4 holes into the straw; each hole should be 2 cm apart from the next. Repeat on the opposite side of the straw if your push pin does not go the whole way through.
4. Pinch the end of the straw (closest to the holes) "hot-dog-style" and tape the straw closed. This will act as a plug to seal the end of the well casing. (Note: The sealed end of the straw must still fit into the bore hole of the box. If not, the ends of the straw may need to be folded in prior to taping. See diagram below.)



5. Pour the syrup into the cup.
6. Starting with the plunger fully inserted into the syringe, begin to draw syrup up into the syringe, being careful to avoid air bubbles if possible. As the syrup is a viscous liquid, it will require some effort to fill the syringe. Ask your lab partner to hold the cup of syrup to avoid spills. Fill the syringe with 100 mL of syrup.
7. Remove the syringe from the cup. Quickly invert the filled syringe so that syrup does not escape through the opening. Be careful not to push on the plunger, as syrup will spurt out.
8. Fit the open end of the straw around the opening of the syringe. Seal with packing tape.
9. Insert the straw into the fracking box through the bore hole. Align the holes on the straw so that they aim out towards the wooden sides of the box, not up and down.
10. With firm pressure, quickly and forcefully inject the syrup into the box. Observe the movement of the beads and syrup as pressure is added and time elapses. Draw a picture of your observations in "Box 2" on the following page. It may be helpful to have your partner video this step so you can watch it again for careful observations. Cell phone cameras work well, if allowable.
11. After all of the syrup has been injected, remove the straw. Observe the beads and fluid again. Draw a picture of your observations in "Box 3" on the following page.
12. Clean up your work area and ask your teacher how to dispose of the gel water beads. Gel water beads can be reused if rinsed and dehydrated. It is recommended that the box be wiped out with warm, soapy water.

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Observations

Box 1	Box 2	Box 3
Before Injection	**During Injection**	**After Injection**

Conclusions

1. Describe the movement of the fluid and why it moved the way it did.

2. Did you notice any movement in the beads? If so, describe and explain why this might have occurred.

3. Explain how this activity models concepts of hydraulic fracturing.

4. No model is perfect—all models have limitations. Describe the limitations of this model. How could you improve this model?

Extensions

- Add solid layers or obstacles to your box and observe how the fluid travels with the obstacles in place. What could these obstacles represent?
- Re-design this model. Would you utilize the same box or a different set-up? Try using different mediums or fracturing fluids in your model.

Fracturing Box Assembly Instructions

Notes About Constructing a Fracturing Box

A fracturing box is best used for demonstration purposes, due to construction and cost. A single box can be constructed for fewer than fifty dollars, and can be used many times. All supplies can be obtained from a local hardware or big-box store. Many of these stores may also be able to assist with cutting supplies to the appropriate size for a nominal fee, or even for free. The construction of the box and the design of the box might also make a great project that could involve students in a technology class or STEM classroom for cross-curricular connections.

**It is encouraged that you find alternative objects to use that may also show the concept without constructing one on your own. Creativity and recycled materials may prove to be better for demonstration.*

Materials

- 2 2″ x 36″ x ⅜″ Pine
- 1 36″ x 1″ x 1″ Square dowel
- 1 2′ x 2′ x ¼″ Plywood
- 1 2″ x 48″ x 1″ Pine
- 1 18″ x 24″ x ⅛″ Plexiglass
- Waterproof wood glue
- Tiny nails
- 2″ Finishing nails
- Tiny drill bit
- 12″ x 6″ Fiberglass window screening
- Clear silicone adhesive
- Staple gun
- Paint or sealant
- ½″ Drill bit
- 1″ Drill bit (option–step 10)

Cut List

- Cut the plexiglass down to 12″ x 15″
- 2 Box sides, from 3/8" pine, 15″ long
- 2 Plexi guides, from 3/8" pine, 15″ long
- 4 Corners, from 1″x 1″ square dowel, 1 1/8″ long
- 2 Guides, from 1″ x 1″ square dowel, 12″ long
- 2 Supports, from 1″ x 1″ square dowel, 2″ long
- 2 Box ends, from 1″ pine, 13″ long
- 1 Box bottom, from ¼″ plywood, 15 ¾" x 13″

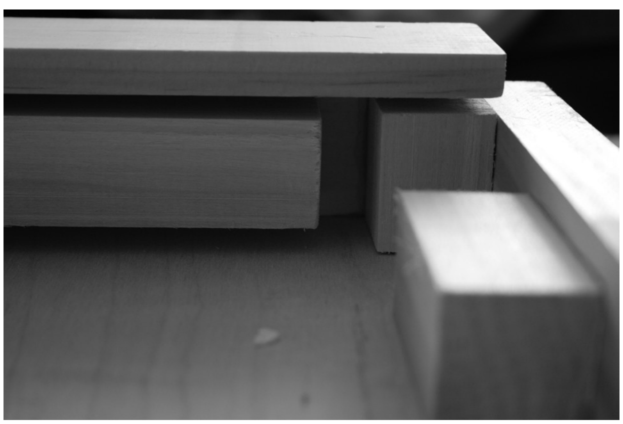
✔ Assembly

1. Attach the corners to the ends of the box sides with tiny nails and wood glue. The corners need to be flush with the ends and bottom edge of the box sides.
2. Attach plexiglass guides to the top of the box sides with tiny nails and wood glue, so that the long edges are even (make an "L"). There should be a space between the plexiglass guide and the corner piece for the plexiglass to fit into.
3. Attach 1 box end to the box sides by first drilling pilot holes, then applying glue and finishing nails to the corners. The side edge should be flush with the top of the plexiglass guides, such that it creates a "stop" for the plexiglass.
4. Attach the other box end to the box sides as in step 3. This time the edge should be flush with the top of the corners. The plexiglass should be able to slide into the box between the guides so it fits into place and stops at the other edge.
5. Attach the long guides (from the square dowel) to the box sides such that they are even with the tops of the corner pieces. This keeps the plexiglass from sagging in the middle of the box.

6. Drill a ½" hole into the center of the box end that will sit below the plexiglass.
7. Attach square dowel supports to the bottom of the box end with the hole in it. This provides an attachment point for the box bottom.
8. Attach two pieces of scrap pine to the box end without the hole. Otherwise, the edge won't meet the box bottom. It makes a nice place for the water to drain out of the box.
9. Attach the box bottom to the box sides and "tall" box end. Also, attach it to the supports of the "short" box end with the hole in it. Use glue and tiny nails. Pilot holes may need to be drilled.
10. Drill a 1" hole into the end of the plexiglass to act as a handle. Alternatively, a piece of wood could be attached to the end of the plexiglass if the hole is problematic. It provides a place to grip the plexiglass.
11. Put the window screening inside the box and staple it to the box end over the open edge. The screen will keep the beads from falling out of the box.
12. Paint or seal the box to prevent leakage and stains.

✪ Alternative Construction Suggestions

1. The box can be constructed with ends and sides all the same thickness, stuck together.
2. Coat the box with a sealant for easy clean-up.
3. Instead of corners, the square dowel could extend the entire length of the box sides, and provide an extra attachment for the ends, as well as a continuous support for the plexiglass when it slides across the box.
4. The craft wood that goes over the plexiglass along the sides is good to have, but if the box is created following suggestion number 1, a stopper for the plexiglass might be necessary. Otherwise, the plexiglass could slide the whole way through.
5. Paint the bottom piece white for easier viewing during the activity.
6. If money or supplies allow, the entire box could be constructed using plexiglass.



PRODUCTION ACTIVITY

Fracturing With Gelatin

Question

How does a liquid behave when injected into a solid under pressure?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- 20 cc Syringe
- Breakfast syrup
- Plastic knife
- Dinner plate
- Flexible straws
- Push pin
- Gelatin block (from your teacher)
- Plastic wrap
- Paper towels

✔ Procedure

1. Your teacher will provide you with a block of gelatin on a plate.
2. Insert a straw into the side of the gelatin block, parallel to the plate, about 2/3 of the way into the gelatin.
3. Bore out the hole with the straw so a hole is left in the gelatin.
4. Poke about 10 holes in another straw. The holes should be near the end, away from the elbow, in two lines on opposite sides of the straw. The holes should be about 5 mm apart, and about 10 mm in from the end of the straw.
5. Cover the end of the perforated straw with a small piece of plastic wrap, to cover the holes while filling with fluid.
6. Attach the other end of the perforated straw, nearest the elbow, to the syringe with another piece of plastic wrap. Wind it around the straw and syringe several times to give a good seal.
7. Pull the plunger out of the syringe.
8. Fill the syringe with breakfast syrup, allowing it to run into the straw. Keep filling the syringe as the level goes down until the entire straw-syringe assembly is full of syrup.
9. Quickly replace the plunger into the syringe. This will keep the syrup from running freely out of the straw, but it still might drip a bit. Remove the plastic wrap covering.
10. Insert the perforated straw, filled with syrup and with syringe attached, into the bored hole in the gelatin block.
11. Using very firm pressure, quickly inject the syrup into the gelatin block and observe the fracturing pattern of the gelatin.
12. Pull the straw back out of the gelatin block.

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Observations

Draw a picture of what you observe happening to the gelatin and the syrup.

Conclusions

1. What happened with the syrup and gelatin in this system? Why did they behave this way?

2. How does the syrup simulate a fracturing fluid in the process of hydraulic fracturing?

3. How could you improve this model?

PRODUCTION ACTIVITY

Fracturing a Cake

Question

How does fracking fluid behave when entering a porous solid?

Hypothesis

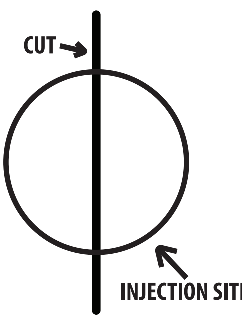
Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- Frozen layer cake
- Turkey injector
- Chocolate Magic Shell® sundae topping
- Cup or beaker (optional)
- Plastic knife

Procedure

1. Assemble the turkey injector syringe and needle.
2. Shake or swirl the Magic Shell® topping thoroughly in your container to prevent hardening.
3. Pour the Magic Shell® into the syringe of the injector. (Magic Shell® can also be drawn up into the syringe if using a beaker or cup. It is recommended that the injector is held over a cup or beaker to reduce mess, as the shell may slowly pour out of the bottom perforation of the injector needle.)
4. Insert injector horizontally into the cake from the side. Aim to insert the injector into the middle or lower layer of the cake, not the top.
5. Quickly and firmly inject the fluid into the cake. (Steps 4-6 should occur quickly to avoid hardening of the Magic Shell®. If the fluid hardens, stir or shake and begin again.)
6. Repeat on other portions of the cake, if necessary.
7. Cut through your cake. Slice so that the knife travels vertically into your injection site creating a cross-section.
8. Observe how the fluid behaved in the porous cake. Draw a picture and describe your observations.



Observations

⁂Conclusions

1. What happened to the Magic Shell® when it was injected into the cake?

2. What would happen to the Magic Shell® if the cake was more or less porous?

3. Did the Magic Shell® travel through the icing that separated the layers? Why do you think it behaved this way?

4. What might the icing represent when using hydraulic fracturing to recover oil and natural gas? Explain.

PRODUCTION ACTIVITY

Understanding Density

Question

Do all liquids have the same densities?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- 100 mL Graduated cylinder
- 600 mL Beaker
- Corn syrup
- Water, dyed with food coloring
- Vegetable oil
- Plastic button
- Grape
- Small cork
- Penny
- Glass marble
- Wooden bead
- Ice cube

Procedure

1. Pour 100 mL each of corn syrup, vegetable oil, and water into the beaker.
2. Let the liquids settle for a few minutes. Observe what happens.
3. One at a time, gently drop each object into the container.
4. Observe where the objects settle.

Conclusions

1. What did you learn about the densities of liquids?
2. What did you learn about the densities of objects?

Extension

ELEMENT	DENSITY AT 20˚C
Hydrogen	0.00008 g/cm^3
Carbon	2.25 g/cm^3
Oxygen	.00131 g/cm^3
Sodium	0.97 g/cm^3
Chlorine	.00295 g/cm^3
Calcium	1.54 g/cm^3
Zinc	7.14 g/cm^3
Bromine	3.12 g/cm^3
Gold	19.32 g/cm^3

Density is defined as mass per unit volume (D = m/v). The density of water is the standard at 1.00 g/cm^3. Discuss the densities of the elements in the chart above. Use the formula for density to calculate the following densities:

- 1000 cm^3 of oil with a mass of 881 g: ________
- 100 cm^3 of aluminum with a mass of 270 g: _________
- 10 cm^3 of copper with a mass of 89.3 g: _______
- 200 cm^3 of nickel with a mass of 1780 g: _______

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PRODUCTION ACTIVITY

Using Density to Extract Petroleum

Question

How can water and gases be used to enhance oil well production?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials *FOR EACH GROUP*

- 500 mL clear Erlenmeyer flask
- Two-hole #7 rubber stopper
- 250 mL Clear beaker
- 30 cm Sections of vinyl tubing to fit rubber stopper
- 150 mL Vegetable oil
- 350 mL Water
- Red oil-soluble dye
- 60 cc Plastic syringe
- Petroleum jelly

✔ Procedure

1. Pour 350 mL of oil into a flask.
2. Mix the red food coloring with 150 mL of water. This will show how oil is less dense and floats. Pour the water into the flask.
3. Insert stopper, and with your fingers covering the holes, shake vigorously.
4. Allow this to settle. Observe what happens to the oil and water.
5. Insert both tubes into the stopper. (Note: Use the petroleum jelly as a lubricant to easily slide the tube into the stopper.) One piece of tubing should reach into the oil layer. Place the opposite end of this tubing into the beaker. The other piece of tubing should reach into the water layer. This tubing's opposite end should remain free.
6. Fill the syringe with water. Using the syringe, slowly discharge the water into the tubing that reaches into the water layer. Expect a short delay, allow for travel time of liquid.
7. Repeat steps 1-5, but instead of the tubing being inserted into the water layer, have it extend into the top of the flask where the air is. Keep the extraction tubing in the oil layer.
8. Pull some air into the syringe, then discharge the air into the tubing that is in the air layer of the flask.
9. As a group, discuss what you observed. Compare and contrast the first activity with the second activity.

Conclusions

1. How can you relate each part of the experimental set-up to the process of getting petroleum out of the ground? Explain each step.

2. How could density be used as a way to force oil out of a well with slowed production?

PROCESSING ACTIVITY

Polymers

Background

During fractional distillation crude oil is separated into useful parts. A petrochemical is a product of the fractional distillation process. Usually consisting of long chains, a monomer is a link in the chain. All of the monomer links connected together make a polymer chain.

Chemically bonded monomers form polymers in a process called polymerization. Polymers created from petrochemicals are synthetic or man-made polymers. We use many of these polymers, such as plastics, everyday.

Question

How do polymers behave?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Polymer One

Materials

- Cornstarch
- Water
- Sealable plastic sandwich bags
- Measuring spoons
- Food coloring
- Paper plates

Procedure

1. Put 6 tablespoons of cornstarch in a plastic bag.
2. Add 5 drops of food coloring.
3. Add 4 tablespoons of water.
4. Close the bag and mix together by kneading.
5. If the polymer seems too runny (you cannot pick it up), add a spoonful of cornstarch to thicken. If the polymer seems too thick or crumbly (dry), add a spoonful of water to make it thinner.
6. Open the bag and pour the polymer onto the plate.
7. Use your finger to gently poke the polymer. What happens?
8. Now quickly poke the polymer. What happens?
9. Pick the polymer up. What happens?
10. Roll the polymer in a ball. What happens?

Conclusion

1. Is this polymer a liquid or a solid? Explain your answer.

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Question

How do polymers behave?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Polymer Two

Materials

- White glue
- Borax
- Water
- Spoon or popsicle stick to stir
- Small paper cup
- Food coloring
- Graduated cylinder
- Ruler
- Sealable plastic sandwich bags

Preparation

- Your teacher may have pre-prepared a borax solution. If not, prepare a borax solution: about 6 mL of borax to 235 mL of water.

Procedure

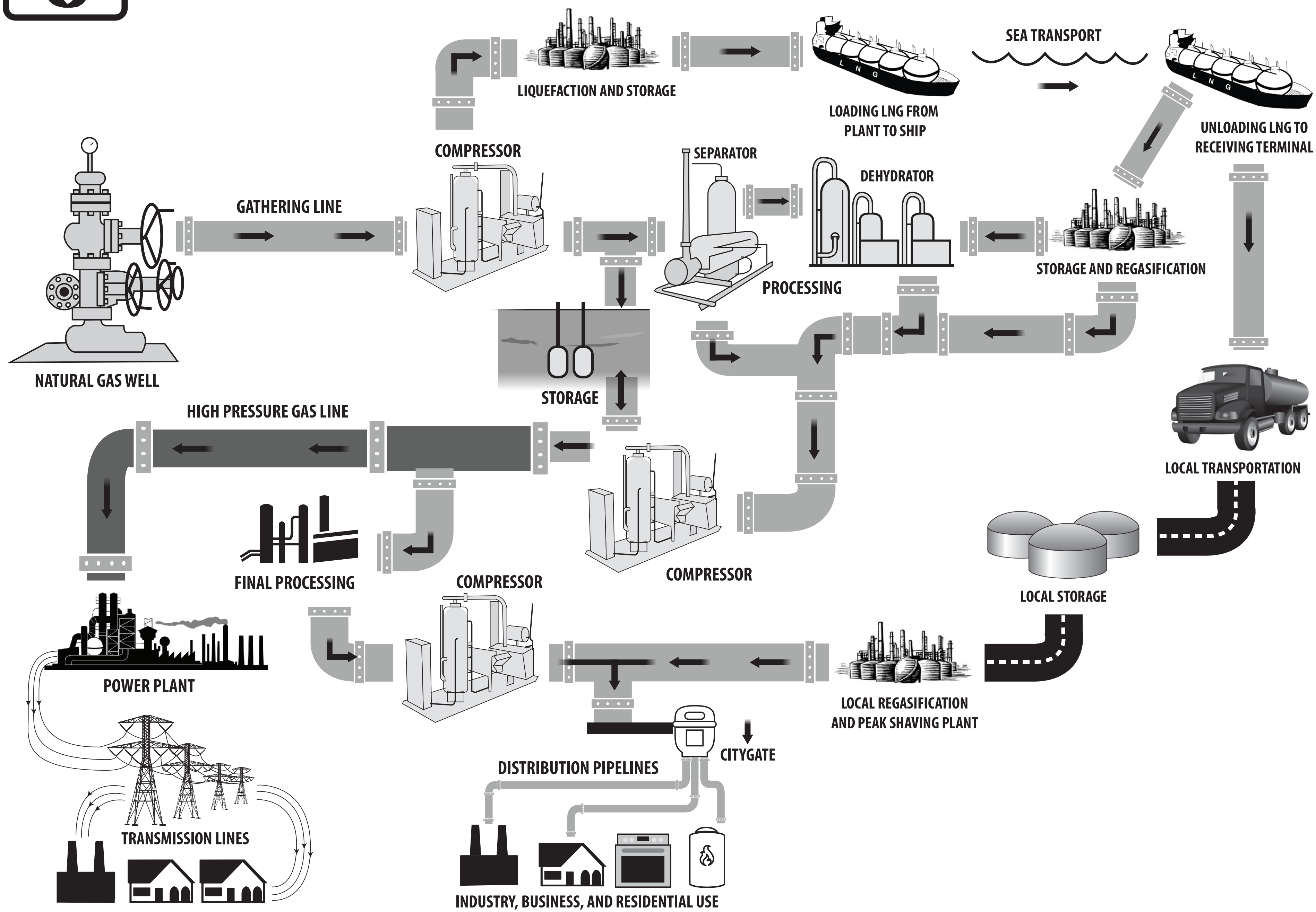
1. Use the ruler to measure and mark 1 cm from the bottom of the small paper cup.
2. Add white glue to the 1 cm mark.
3. Add a few drops of food coloring and mix.
4. Measure 7 mL of water in the graduated cylinder and add to the glue. Mix well and pour into a plastic bag.
5. Measure 8 mL of the borax solution using the graduated cylinder and add to the glue solution in the plastic bag. Mix well by kneading.
6. If it is too sticky, add borax solution one drop at a time. If it is too stringy, add glue one drop at a time.
7. Once the polymer is formed, you may remove it from the plastic bag and knead it.
8. Pull your polymer apart, string it out, twist it, and roll it into a ball.
9. Write your observations about your polymer.

Conclusions

1. What happened when you combined the glue solution and the borax solution?

2. Explain how this is a polymer.

Natural Gas Production to Market



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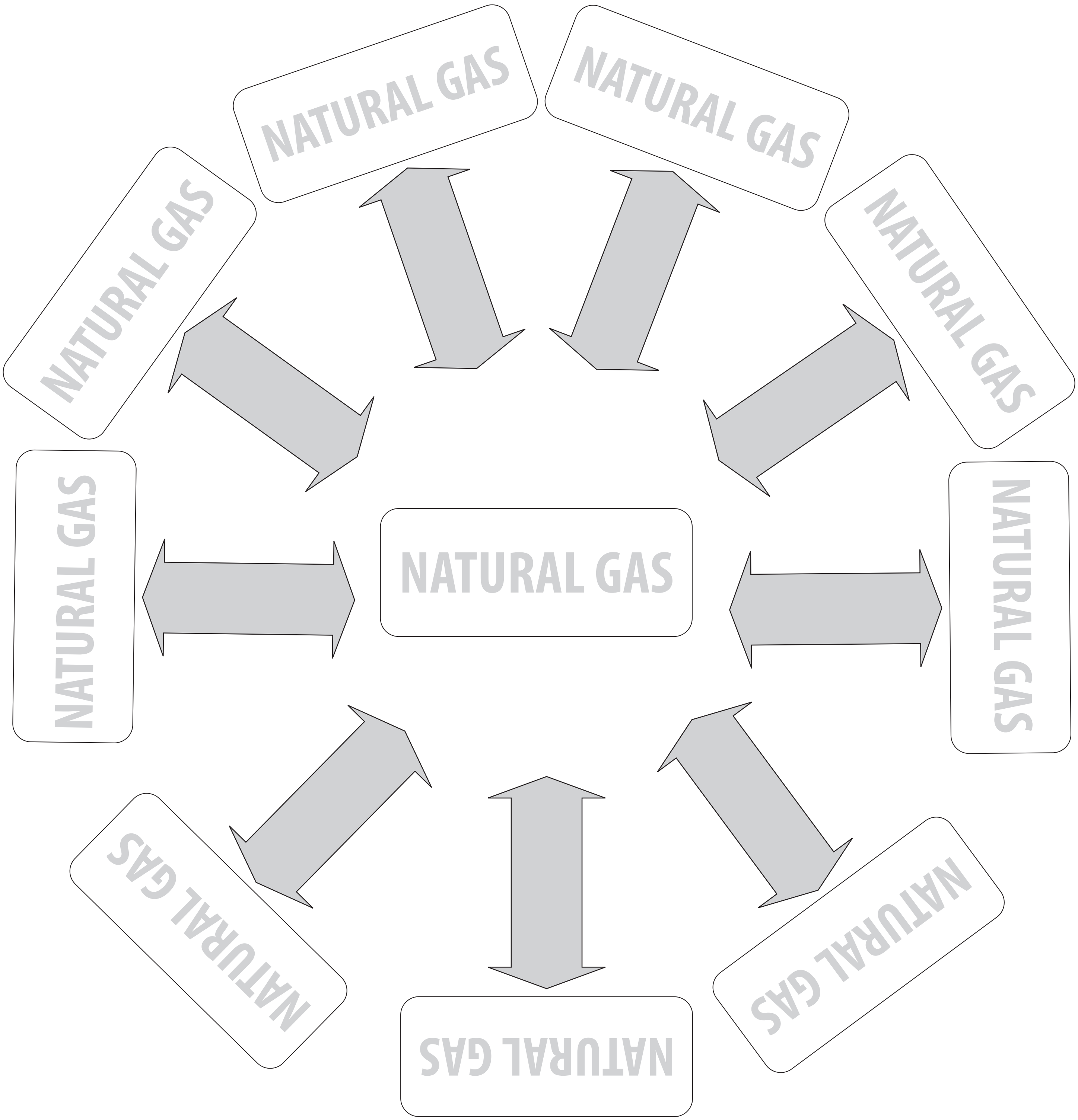
Natural Gas as a System

Exploration	**The process of finding natural gas deposits.**
Production	**The process of drilling wells and bringing hydrocarbons to the surface.**
Separation and Dehydration	**The process of removing water vapor and liquid aerosols from natural gas so it is of a good quality for pipeline transportation.**
Storage	**Underground formations can be used to store natural gas at low demand times, so it is available at peak demand times. LNG can be stored in insulated tanks until needed.**
Liquefaction	**The process by which natural gas is converted into a liquid.**

Transportation	**Natural gas is moved through an extensive network of interstate and intrastate pipelines or by tanker or truck as LNG.**
Compression	**Increasing the pressure of natural gas at compressor stations every 50-100 miles along the pipeline system.**
Distribution	**Utility companies deliver natural gas to consumers through a network of pipelines and a citygate.**
End Use	**Industry, businesses, and residential users all need natural gas for heating, cooking, manufacturing products, and generating electricity.**
Regasification	**The process by which LNG is heated, converting it into its gaseous state.**

The Natural Gas Chain

Choose one step in the NG chain and write it in the center box. Label the outside boxes with the nine remaining steps. In the arrows connecting the NG steps, write a way the center step affects the outside step as well as a way the outside step affects the inside one.



A Nifty Natural Gas Story

Hundreds of millions of years ago, long before the dinosaurs roamed, most of the Earth was covered with vast, deep oceans. Tiny plants and animals lived in these oceans.

The sun produces lots of light from a process called nuclear fusion. The sun's radiant energy was changed into chemical energy by the plants, which helped them grow. The animals ate the plants, and both the plants and animals stored the sun's energy in their bodies as chemical energy.

When they died, they sank to the ocean floor. As more and more plants and animals died, they sank and made a thick layer deep under the water.

Over time, more layers of rock, sand, and other dead plants and animals built up. As the layers built up, they pressed down hard on the layers beneath.

As the layers of rock built up, the deepest layers got hot. They were under very high pressure with all that weight on top of them. They waited some more - millions of years!

Eventually, those dead plants and animals under all those layers of rock changed. Now they weren't plants or animals. Now they were special molecules called hydrocarbons, with only hydrogen and carbon in them. The hydrocarbons became trapped in tiny holes in the rocks. Then they waited.

Many years ago, people began to notice bubbles coming out of the ground beneath ponds and lakes. They discovered that the bubbles were flammable – they could fuel a fire. The people used bamboo and other hollow plant stems to carry the bubbling gas to their villages.

Today, geologists search for the layers of rock that contain the hydrocarbons. They use a lot of special equipment and computers to find natural gas. Then they drill an exploratory well. Eight or nine times out of ten, they are successful!

The natural gas is pumped out of the ground at the well. It is separated from any liquids and water that might be mixed with it, and compressed into high pressure gas pipelines. The gas moves to the processing facility.

Natural gas has no odor, so at the final processing facility, a chemical called mercaptan is added. Mercaptan smells like rotten eggs! That is what you smell if natural gas is leaking. Because it is flammable, it is important to use it safely. If you ever smell natural gas, leave the area immediately and then call 911.

After processing more pipelines carry natural gas to where it is used. Electrical power plants might use natural gas to generate electricity for homes, businesses, and schools. Most homes also use natural gas to heat water and stay warm in cold weather.

Natural gas produces almost no air pollution when it is burned. All of those tiny plants and animals millions of years ago are now providing us a clean energy source that is easy to use. Do you think they would be happy to know so many people rely on them?

A Nifty Natural Gas Story Pantomime

Students will demonstrate the flow of energy to heat homes using props. Depending on the audience, signs with the different forms of energy can be used by the students to identify the energy transformations. This activity with different props can also be used to demonstrate other energy flows, like coal to electricity, biodiesel, ethanol, etc.

Earth – Oceans		The earth was covered with vast, deep oceans. Tiny plants and animals lived in those oceans
	Prop & Action	Blue ball
Sun – Nuclear Energy to Radiant Energy		Nuclear fusion in the sun produces vast amounts of energy. The sun's radiant energy is transferred to Earth by electromagnetic waves.
	Prop & Action	Yellow ball; long yellow ribbons waved in the air away from the ball
Plants – Radiant Energy to Chemical Energy		Radiant energy from the sun is absorbed by tiny green plants in the ocean and changed to chemical energy by photosynthesis
	Prop & Action	Artificial plans or paper "seaweed"; students move up from the floor and "float" around
Storing Chemical Energy		Tiny animals in the ocean ate the plants and stored their chemical energy.
	Prop & Action	Sock puppets; sock puppet animals "eat" the plants
Animals changing to Natural Gas		The plants and animals died and they sank to the bottom of the ocean, where they were covered by layers of rocks and soil.
	Prop & Action	Large pieces of brown and black paper and cardboard (several different types and colors); The sock puppets are dropped to the floor and a couple layers of "sediment" are stacked on top of them
Burying		Over millions of years, more and more rocks and soil layered on top of the plants and animals.
	Prop & Action	Add more layers of paper "sediment"
Heat, Pressure, Time		As the layers of rocks and soil got thicker and thicker, more and more pressure built up over the plants and animals. The pressure made the temperature increase. Over a long time, the pressure and temperature kept increasing, and the plants and animals changed into natural gas.
	Prop & Action	Place a heavy rock or some heavy books on the paper "sediment." Students hold a large thermometer and a large clock, representing heat and time

Bubbles of gas		The natural gas was trapped in tiny holes in the rocks.
	Prop & Action	Bottle of bubbles
Natural Gas Exploration and Production		A well is drilled into the ground to locate natural gas. The gas is brought out of the ground through the well.
	Prop & Action	Long, hollow cardboard tube, or a rolled-up piece of paper; hold the tube vertically with hands over the head, and push the tube downward to the floor. Use one hand to wave fingers over the top of the tube in a wiggling motion to indicate the flowing of natural gas.
Separation, Dehydration, and Compression		The raw natural gas from the ground is separated from impurities and water, and compressed to high pressure.
	Prop & Action	Plastic mixing bowl or bottle; student uses hand to simulate separating the gas from the impurities, and another student pushes both hands together in a compressing motion to load the "gas" into the "pipeline"
Processing		At the processing facility a chemical called mercaptan is added to the gas to make it smell like rotten eggs. If you ever smell natural gas, leave the area immediately and call 911.
	Prop & Action	One long piece of garden hose or other tubing, and one eye dropper; one student holds the tubing from the separator to the processing facility, and one student holds the end of the tubing in one hand and the dropper in the other. The dropper is used to simulate adding mercaptan to the gas
Distribution		The processed gas is transported by pipeline to businesses and homes.
	Prop & Action	Another long piece of garden hose or other tubing; student holds it between the processing facility and the end use location
End Use – Chemical Energy to Electricity or Thermal Energy		Electric utilities burn natural gas to boil water into steam and turn a turbine, generating electricity. In our homes, natural gas is burned to heat water and keep us warm in cold weather.
	Prop & Action	Small lighter; rope to represent transmission lines; Student lights lighter and other students hold their hands to flame to warm them.

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Careers in the Natural Gas Industry

There are three segments of the natural gas industry: upstream, midstream, and downstream. Exploration and production activities are part of the upstream segment. Midstream activities include transport, storage, and marketing of crude markets. The downstream segment includes processing, chemical refining and marketing, and the distribution of products. All of the following careers fit into one of these segments. While not all of these careers are strictly employed within the natural gas industry, all are important to its function.

Architect
Surveyor
Civil Engineer
Electrical Engineer
Mechanical Engineer
Petroleum Engineer
Architectural and Civil Drafter
Surveying and Mapping Technician
Civil Engineering Technician
Electronics Engineering Technician
Environmental Engineering Technician
Mechanical Engineering Technician
Chemical Technician
Occupational Health and Safety Technician
Construction Manager
Supply Chain Manager
Risk Management Specialist
Supervisor of Construction and Extraction
Supervisor of Installers, Mechanics, Repairers
Supervisor of Production and Operation
Production, Planning, and Expediting Clerk
Carpenter
Construction laborer
Operating Engineer
Pipelayer
Plumber, Pipefitter, Steamfitter
Construction and Building Inspector
Derrick Operator
Rotary Drill Operator
Service Unit Operator
Earth Driller
Roustabout
Extraction Worker
Mobile Heavy Equipment Mechanic
Industrial Machinery Mechanic
Electric Power-line Installer and Repairer
Telecommunications Line Installer
General Maintenance and Repair Worker
Installation, Maintenance, Repair Worker
Machinist
Welder, Cutter, Solderer, Brazer
Plating and Coating Machine Setter, Operator, and Tender, Metal and Plastic
Gas Compressor and Gas Pumping Station Operator
Wellhead Pumper
Heavy Truck and Tractor Driver
Industrial Truck and Tractor Operator

Career Networking Template

LinkedIn™

Steve Surveyor

Surveying Engineer | Map It Mine It Market It, Inc.

Pennsylvania

Current	Map It Mine It Market It, Inc.
Past	Photogrammetric Technician, Map It Mine It Market It
Education	Michigan Technological University

National Society of Professional Surveyors http://www.nsps.us.com/index.cfm?&stopRedirect=1
Michigan Technological University http://www.mtu.edu/admissions/programs/majors/surveying/

Summary

Engineer working for Map It, specializing in GIS technology and photogrammetry.

Specialties

- GIS technology
- Photogrammetry
- Digital Cartography

Education

Michigan Technological University
Bachelor of Science, Surveying Engineering

Experience

Map It Mine It Market It, Inc.
2007 – present

- Develop contoured mapping data for natural gas exploration
- Contribute to site development planning for natural gas production
- Manage surveying team of 7-10 individuals on site

Current

Past

Education

Summary

Specialties

-
-
-

Education

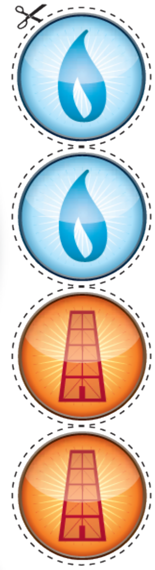
Experience

-
-
-
-

Oil and Natural Gas Career Game

Imagine you are a drop of oil or a molecule of natural gas. Cut out the game pieces to the right and roll a die to follow the path from the ground to market. Along the way, you will meet many people who help you on your journey.

GAME PIECES



START

GEOLOGISTS explore the nature and structure of rock layers in order to determine the best possible places to drill for oil and natural gas.

GEOSCIENTISTS AND HYDROLOGISTS study the composition, structure, and other physical aspects of the earth to analyze the composition of earth, rock, and water.

PETROLEUM GEOLOGISTS gather, process, and analyze seismic data and well data to locate drill sites.

PETROLEUM ENGINEERS formulate the general plan for how the extraction operation will go. They help design the general structure of the well and the most efficient method of extraction.

EXPLORATION

Geologists conduct many tests gathering information, such as seismic data, to determine if the geology holds oil or natural gas.

ENVIRONMENTAL ENGINEERS ensure that well sites meet federal, state, and local regulations. They also plan reclamation projects when extraction is complete.

ROTARY DRILL OPERATORS supervise the crew and operate machinery that controls drilling speed and pressure.

ROTARY-RIG ENGINE OPERATORS are in charge of engines that provide the power for drilling and hoisting.

DERRICK OPERATORS work on small platforms high on rigs to help run pipe in and out of well holes and operate the pumps that circulate mud through the pipe.

DRILLING & PRODUCTION

Wells are drilled deep into the ground to bring oil and natural gas to the surface.

ROUGHNECKS guide the lower ends of pipe to well openings and connect pipe joints and drill bits.

INSTRUMENTATION TECHNICIANS maintain, calibrate, adjust, and install measuring and control instruments necessary to ensure the safe, efficient operation of equipment.

ROUSTABOUTS are general laborers that do general oilfield maintenance and construction work, such as cleaning tanks and building roads.

ELECTRICIANS maintain and repair the electrical and electronic equipment and systems that keep the facilities up and running.

MACHINISTS install, maintain, repair, and test rotating mechanical equipment and systems.

REFINING & DISTRIBUTION

Crude oil and natural gas are refined into many different products and shipped to consumers.

CHEMICAL ENGINEERS design chemical plant equipment and develop processes for manufacturing chemicals and products like gasoline, detergents, and plastics.

PUMP SYSTEM OPERATORS, REFINERY OPERATORS, AND GAUGERS control the operation of refining and processing units.

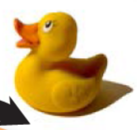
PROCESS PIPING OR PIPELINE DRAFTERS prepare drawings used in the layout, construction, and operation of oil and gas fields and refineries.

ENERGY TRADERS buy and sell oil and gas in the U.S. and international markets.

STOP! Roll the die one last time to find out what kind of product you will become. If you are a drop of oil, follow the petroleum path. If you are a molecule of natural gas, follow the natural gas path.

END-USE PRODUCTS

PETROLEUM



1. You are refined into gasoline for use in cars and trucks.
2. You are made into plastic and become part of a toy.
3. You are processed into the wax that becomes a crayon.
4. You are part of medicine that helps save a person's life.
5. You are used to make asphalt, which paves a new highway.
6. You are refined into jet fuel and travel the world in first-class.

FINISH

NATURAL GAS

1. You are sent to a house and used to cook dinner on a stove.
2. You are used as fuel in a power plant that generates electricity.
3. You are compressed and used as an alternative fuel in a city bus.
4. You are piped to a factory where you help make cars.
5. You are a raw material used to make paint.
6. You are sent to a house and used for space and water heating.

FINISH

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Peak Oil Game

Question

What factors affect the production of a well over time?

Hypothesis

Draft a hypothesis to answer the question using an "If...then...because..." format.

Materials

- Team notebook
- Jars of beans ("oil field")
- Three containers (such as tubs or paper bags)
- Small spoons
- Digital balance

Procedure

1. Form teams of 3-5 students.
2. One person will be the driller, and one person will be the processor.
3. You will receive a set of jars that represent your oil field, one spoon, and three containers. One container is for **processing oil**, one is for **refined oil**, and the third is for **accumulated oil**. There is also a communal waste container for the class to use.
4. Each jar contains a mixture of black beans (oil), pinto beans (dirt and other contaminates), and rocks (obstacles).
5. You may mine the oil from any jar in any order. However, you may not move or pick up the jars, lean them over, use your fingers to extract beans, or pull out the rocks. You may only use your spoons to scoop beans out of the jars. The jars must not move.
6. Your teacher will set the timer for 30-60 seconds (one "year") and tell you to begin.
7. During each timed period, your goal is to get as much clean oil into the team's **refined oil container** as possible. You will be penalized for contaminated oil and for oil and waste spilled outside of the containers.
8. One container will be used as the **processing plant** in which you separate the beans before placing them into the **refined oil container**.
9. The processing and drilling must take place at the same time, and stop after the timer goes off. All activity stops immediately, and scoring occurs.
10. For each pinto bean (dirt) in the **refined oil container**, two black beans are removed from the **refined oil container**. Also remove the pinto beans.
11. For any bean spilled outside the containers, two black beans are removed from the **refined oil container**.
12. All spilled and unprocessed oil must be discarded into the communal waste container for the classroom.
13. Measure each year's production by weighing the beans that remain in the **refined oil container** after penalties. Record the production in the team's notebook.
14. Add the current year's total to the team's **accumulated oil** storage container. You will use this stored oil to purchase tools and employees for your team.
15. You may purchase better tools and hire more staff in between rounds. Your teacher will tell you how much each item costs. Be careful! The price of tools and staff will likely change as the game continues.

Conclusions

1. Use a computer or graph paper to graph your team's yearly production. How does your graph compare to the real oil production graphs for the U.S. and world oil production? (http://tonto.eia.doe.gov/dnav/pet/hist/mcrfpus2a.htm)
2. Did the oil in your oil field really run out?
3. Estimate the percent of the original oil left in your oil field.
4. How is this model similar to the real world?
5. How is this model different from the real world?
6. Why might companies stop purchasing technology to produce oil from a well, or choose to abandon it?

APPLICATION ACTIVITY

Road Trip

The Challenge

Energy is required to transport you from place to place. In the United States, the transportation sector consumes 29 percent of total energy supply and is responsible for about one-third of the greenhouse gases emitted each year.

Plan a four day road trip vacation. Where would you go? What stops would you make along the way?

1. Select a vehicle make and model for your trip, then find its fuel economy ratings at www.fueleconomy.gov. Fill in the information below.

   Vehicle Make and Model: ____

   Fuel Type: ______________________ Fuel Economy (MPG): ______________________

2. In the chart's left hand column, plan out each segment of your trip. Use the data and formulas provided below to calculate how many gallons of fuel will be required, and the amount of CO_2 emissions produced.

The EIA uses the following CO_2 emission values. Circle the value you will use in your calculations.
Gasoline CO_2 Emissions = 19.6 pounds/gallon
Diesel CO_2 Emissions = 22.4 pounds/gallon
Miles Driven/MPG = Total Gallons Consumed
Total Gallons Consumed x CO_2 Emissions lbs/gal = Total CO_2 Emissions (lbs)

TO	FROM	MILES	GALLONS CONSUMED	TOTAL CO_2 EMISSIONS

Answer the Following Questions

1. Why did you choose the vehicle you chose?
2. What is the total amount of CO_2 emissions associated with your trip?
3. What is the price of fuel in your area? How much will fuel cost for the entire trip?
4. Are there ways you can reduce your fuel consumption on this trip? Explain.
5. Are there some portions of your trip where you can use public transportation? Why or why not?
6. How would using public transportation compare to driving your own personal vehicle?
7. A 2014 Volkswagen Jetta using diesel fuel is rated to get mileage of up to 42 MPG. A 2014 Volkswagen Jetta using regular gasoline gets 26-36 MPG. Which car would be better to take on your road trip? Use data to explain your reasoning.
8. Can you find a less expensive, less carbon intensive vehicle than your first vehicle choice? Find at least two alternatives and explain how they compare to your original vehicle.

Resources: For more information on alternative fuel vehicles, visit the U.S. Department of Energy's Alternative Fuels and Advanced Vehicles Data Center at www.afdc.energy.gov/fuels/.

Petroleum Industry in the Round Cards

I have Alteration. Who has a name for fuels formed from the remains of ancient sea plants and animals?	**I have Petroleum.** Who has the area that produces one-sixth of all crude oil in the U.S.?
I have Fossil Fuel. Who has the term for energy sources that take hundreds of millions of years to form and can not be easily replenished?	**I have Offshore.** Who has the sector of the economy that uses almost three-fourths of U.S. oil?
I have Nonrenewable. Who has the name of the main component of natural gas?	**I have Transportation.** Who has the type of rock that is formed from magma?
I have Methane. Who has the type of rock made from layers of sand and sediment?	**I have Igneous.** Who has the type of gases that keep the Earth warm enough for life?
I have Sedimentary. Who has the energy source consumed the most in the U.S.?	**I have Greenhouse.** Who has the type of rock made from extensive heat and pressure on other rocks?

I have Metamorphic. Who has the study of rock layers to determine the origin and composition of rocks?	**I have CAVE.** Who has a new type of seismic technology that measures changes over time?
I have Stratigraphy. Who has the measure of a rock's ability to hold and move fluids?	**I have 4D Seismic.** Who has the structure used to drill for underground oil with an exploratory well?
I have Permeability. Who has the technology that uses sound waves to explore underground rock formations?	**I have Drilling Rig.** Who has the term for petroleum products that are used to make other products in chemical plants?
I have Seismic. Who has a device used to create underground shock waves?	**I have Feedstocks.** Who has the term for the rock that is disturbed by the drilling process?
I have Thumper Trucks. Who has an advanced visualization technology used to understand seismic data?	**I have Debris.** Who has the term for the material used to lift debris from a well?

I have Drilling Mud. Who has the term used to describe the gaps or pores where oil is stored?	**I have Blow Out Preventor (BOP).** Who has the term used when a well has enough pressure to lift the oil?
I have Porosity. Who has the process used to turn an exploratory well into a production well?	**I have Natural Drive.** Who has the process of separating crude oil into its major components using boiling range?
I have Completion. Who has the term used to indicate the amount of water in an oil deposit?	**I have Distillation.** Who has the process of using heat to break long hydrocarbon chains into smaller chains?
I have Saturation. Who has the term that describes nearby oil reserves that are not connected to each other?	**I have Thermal Cracking.** Who has the process of combining short hydrocarbon chains into longer chains?
I have Compartmentalization. Who has the device used to regulate high pressure in a production well?	**I have Unification.** Who has the process of rearranging the molecules in hydrocarbon chains?

Natural Gas in the Round Cards

I have 811. Who has the name of natural gas trapped within coal seams underground?	**I have Fredonia, New York.** Who has the sector of the economy that uses natural gas to manufacture products?
I have Coalbed Methane. Who has a device that removes water from natural gas?	**I have Industry.** Who has what you should do if you smell natural gas?
I have Dehydrator. Who has the sector of the economy that burns natural gas to generate electrons moving through a conductor to power devices?	**I have Leave Immediately and Call 911.** Who has the facility that processes natural gas into a liquid?
I have Electric Power. Who has the name for determining likely locations of natural gas deposits?	**I have Liquefaction Plant or Export Facility.** Who has energy sources that are not easily replenished?
I have Exploration. Who has the site of the first natural gas well?	**I have Nonrenewable.** Who has the device that is most often used to transport natural gas?

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I have Pipeline. Who has the step in the natural gas chain that includes natural gas wells?	**I have Peak Shaving Facility.** Who has the machine that increases the pressure of natural gas so it can be transported?
I have Production. Who has the type of rock formed by layers of silt, soil, and other deposits?	**I have Compressor.** Who has when natural gas is sent to various sites for end use?
I have Sedimentary. Who has a type of rock in which natural gas can often be found?	**I have Distribution.** Who has the ability to do work or cause a change?
I have Shale. Who has two states that produce the most natural gas?	**I have Energy.** Who has the name of energy sources produced from ancient plants and/or animals?
I have Texas and Pennsylvania. Who has a facility that uses stored natural gas during peak-use periods?	**I have Fossil Fuel.** Who has a class of molecules made from only hydrogen and carbon that includes natural gas?

I have Hydrocarbon. Who has the name for natural gas produced where trash is deposited?	**I have Porous.** Who has the sector of the economy that uses natural gas primarily to heat water and living spaces?
I have Landfill Gas. Who has the chemical with a strong odor that is added to natural gas so it can be detected without special equipment?	**I have Residential.** Who has the device that isolates natural gas from liquids and other contaminants when it comes out of the well?
I have Mercaptan. Who has the amount a volume of natural gas is reduced when it becomes a liquid?	**I have Separator.** Who has the step in the natural gas chain where natural gas is held until times of high demand?
I have 600 Times. Who has the property of rocks which allow fluids to easily move?	**I have Storage.** Who has the site where a hole is drilled into the ground to obtain natural gas?
I have Permeable. Who has the property of rocks that can hold lots of fluids?	**I have Well.** Who has the number everyone must call to locate natural gas pipelines before digging?

OIL AND NATURAL GAS BINGO

A. Knows the main component of natural gas

B. Can name a state that is a top 5 producer of petroleum

C. Knows what percentage of oil used in the U.S. is imported

D. Knows how natural gas is measured

E. Knows two ways to increase a car's MPG

F. Knows what percentage of U.S. electricity is generated by natural gas

G. Knows the type of rock most petroleum is found in

H. Knows two industrial products that use natural gas as a feedstock

I. Knows what percentage of total energy is supplied by petroleum

J. Used petroleum to get to school today

K. Knows two uses of natural gas in the home

L. Knows the two types of atoms found in oil and natural gas molecules

M. Has seen crude oil

N. Knows the method refineries use to separate crude oil into useful products

O. Knows how natural gas is transported

P. Knows what OPEC stands for

A NAME	**B** NAME	**C** NAME	**D** NAME
E NAME	**F** NAME	**G** NAME	**H** NAME
I NAME	**J** NAME	**K** NAME	**L** NAME
M NAME	**N** NAME	**O** NAME	**P** NAME

Glossary

alkene	hydrocarbon that contains at least one double bond between two carbon atoms
alkylation	a refinery operation that adds high octane hydrocarbons to motor and aviation gasoline in order to meet the required engine octane ratings
alloy	a mixture of metals and sometimes other elements
alteration	a process that reformulates long hydrocarbon molecule chains so they are branched; branched hydrocarbons burn more smoothly than long-chain hydrocarbons
aromatics	a group of petrochemicals with a distinctive sweet smell that are characterized by ring structures
Bishop Process	a process where LNG is offloaded and injected into subsurface geologic formations called salt caverns
blow out preventer	a safety device or valve used to prevent uncontrolled flow of fluids from a well
boiling point	the temperature at which any substance boils at standard atmospheric pressure
catalyst	substance that speeds up a chemical reaction without itself being consumed by the reaction
catalytic cracking	the use of a catalytic agent to break complex hydrocarbon molecules into simpler and lighter molecules
catalytic reforming	a refinery process that uses a catalyst to combine or unify low weight hydrocarbons into materials that are used for gasoline and other chemicals
CAVE	Cave Automatic Virtual Environment - sophisticated technology for visualizing data from seismic systems
chemical property	characteristic of a substance that describes how it will react with another substance, such as flammability, oxidizer, etc.
Christmas tree	a series of valves and gauges that control the flow of a well with natural drive
clathrate	ice structure formed at low temperature and high pressure that forms a cage around gas molecules
coke	a carbon-rich substance used by heavy industry as a source of thermal energy
coking	heating residue from the petroleum distillation process to produce useful products such as coke
combined-cycle	power plants that use a fuel to power a combustion turbine and a steam turbine, essentially using the fuel twice in different cycles
combustion	chemical reaction where oxygen is a reactant; another name for combustion is burning
compartmentalization	the segregation of or trapping of fluid by barriers underground, such as faults
compressor	machine that applies a force to a gas, decreasing its volume and consequently increasing its pressure
condenser	a system that is used to turn a gaseous substance into a liquid; condensers in power plants turn steam from the turbine into water
cracking	a chemical reaction process that breaks long hydrocarbon chains into shorter chains
crude oil	a mixture of hydrocarbons existing in liquid form in natural underground reservoirs; petroleum as it is before the refining process
density	amount of volume a certain mass occupies; the mass of an object divided by its volume is its density
derrick	the large tower that houses all of the drilling equipment above the drilling site
distillation	separation of substances based on their boiling point range
distributed energy	energy that is generated and stored very close to where it is used
energy	the ability to do work or cause a change
feedstock	raw material used in processing and manufacturing
fluctuation	repeated increases and decreases
fossil fuel	energy-rich substance formed over long periods of time and under great pressure from the ancient remains of organic matter
fractional distillation	separation of volatile compounds with differing boiling points through gradual increase of temperature
fractioning tower	equipment in which distillation takes place

generator	a device that turns mechanical or motion energy into electrical energy; the motion energy is sometimes provided by an engine or turbine
geophone	an electronic receiver that picks up seismic vibrations
gravimeter	device that is able to measure very slight differences in gravitational force, and used to detect less dense rocks where oil or natural gas might be located underground
greenhouse gas	gas in the atmosphere that traps in thermal energy as part of the greenhouse effect
heat exchanger	any device that transfers heat from one fluid (liquid or gas) to another or to the environment
heat of combustion	the amount of energy that can be obtained from the combustion of a substance
horse head pump	a pump with a crank arm that lifts oil to the surface of a production well
hydraulic fracturing	a drilling method that utilizes high pressure liquids to create fissures in formations of rock with tightly packed pores, allowing oil and natural gas to flow through the cracks
hydrocarbon	a chemical compound containing only hydrogen and carbon
hydrophone	microphone designed to be used underwater; converts sound signals into electrical signals
igneous rock	rock formed through volcanic activity
kinetic energy	energy of motion, such as moving electrons (electricity) or moving water
liquefaction	the process by which a gas is converted into a liquid
liquefied natural gas	natural gas that has been converted to a liquid by cooling it to temperatures below -260°F/-162.2°C; when cooled to become LNG, natural gas' volume is reduced 600 times
magnetometer	a device used to measure the strength or direction of a magnetic field
mercaptan	an odorant added to natural gas as a safety feature so it can be easily detected
metamorphic rock	rock with few pores made from sedimentary or igneous rock under intense pressure
methane	the main ingredient in natural gas
methane hydrate	crystalline substance consisting of water molecules held in place with hydrogen bonds between them, and methane molecules trapped in the crystal lattice
mud	in the petroleum industry, a fluid that is a mixture of substances with a specific density used to cool a drill bit and remove debris when drilling an oil or gas well
naphtha	least dense liquids in a mixture of hydrocarbons
natural gas	a gaseous mixture of small hydrocarbon compounds, the primary one being methane
non-porous	unable to be permeated by water or fluids
nonpolar	molecule where all electrons are shared evenly
nonrenewable energy source	an energy source that takes millions to hundreds of millions of years to form and cannot be replenished quickly
olefin	a class of hydrocarbons recovered from petroleum that contain one or more pairs of carbon atoms linked by a double bond
peak oil	the point in time when the maximum production of petroleum will be reached and supplies begin to decrease
peak shaving facility	a facility that diverts natural gas from the pipeline at times of low demand, liquefies, and stores it until periods of high demand
permeability	measure of how well a fluid can penetrate a porous substance; the ability of a rock to hold fluids
petroleum	a liquid mixture of hydrocarbons formed from the decay of ancient sea life
physical property	characteristic of a substance that is independent of any other substance, and can be determined without changing the composition of the substance, such as boiling point, melting point, polarity, physical state, solubility, and density

pig	a cleaning device used in pipelines to remove sediment and maintain the pipeline, without interrupting production
polar	molecule where all electrons are not shared evenly among atoms
polymer	a large organic molecule formed by combining many smaller molecules (monomers) in a regular pattern
pore	small hole or opening in a solid
porosity	measure of the number or size of pores, or gaps between grains of a rock; objects with a high porosity contain many pores
porous	filled with holes or pores allowing fluids to permeate
potential energy	stored energy, such as gravitational or chemical energy
propane	a normally gaseous, straight-chain hydrocarbon; it is a colorless paraffinic gas that boils at a temperature of -43.67 degrees Fahrenheit; it is extracted from natural gas or refinery gas streams
refinery	a facility where petroleum products are separated into usable by-products
refrigerant	a substance used to aid in the cooling process; phase changes are often involved
regasification	the process in which a liquefied substance is warmed or heated, converting it to its gaseous state
renewable energy source	an energy source that can be replenished in a short period of time
roustabout	a worker on a drilling rig
ROVER	a Remote Operating Vehicle used to maintain and repair undersea drilling equipment
salt cavern	an underground location for the storage of LNG; see also "Bishop Process"
satellite	a plant that stores LNG off-site from the import facility for use during peak demand
secondary source of energy	source of energy that must be obtained from another source, such as electricity or hydrogen
sedimentary rock	rock formed from layers of sand and sediment under pressure
seismic	of or relating to vibrations in the Earth
seismic technology	equipment that uses reflected sound waves off underground rock to determine the characteristics of rock formations
separator	a device used to separate oil and natural gas from each other and from the other liquids and impurities recovered
shale plays	formations containing significant accumulations of natural gas
stranded resources	resources that are located in an area that makes them difficult to recover or transport
strata	rock layers
stratigraphy	the study of rock layers to determine data about the rock formation, age of the layers, radioactivity, etc.
subsidy	financial assistance paid to an individual, business, or sector of the economy, usually by the government
subterranean	existing or situated underground
tank farm	a group of storage tanks to store fluids for use or processing
thermal cracking	a process that uses very high temperatures to break apart long hydrocarbon chains
unification	chemical reaction that combines small hydrocarbons into one or more larger molecules
viscosity	fluid property describing its resistance to flow—water has a thin or low viscosity and syrup is thick with a high viscosity
volcanic rock	rocks that originated from the eruption of a volcano

Exploring Oil and Natural Gas Evaluation Form

State: ____________ **Grade Level:** ____________ **Number of Students:** ___________

1. Did you conduct the entire unit?	❑ Yes	❑ No
2. Were the instructions clear and easy to follow?	❑ Yes	❑ No
3. Did the activities meet your academic objectives?	❑ Yes	❑ No
4. Were the activities age appropriate?	❑ Yes	❑ No
5. Were the allotted times sufficient to conduct the activities?	❑ Yes	❑ No
6. Were the activities easy to use?	❑ Yes	❑ No
7. Was the preparation required acceptable for the activities?	❑ Yes	❑ No
8. Were the students interested and motivated?	❑ Yes	❑ No
9. Was the energy knowledge content age appropriate?	❑ Yes	❑ No
10. Would you teach this unit again?	❑ Yes	❑ No

Please explain any 'no' statement below.

How would you rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor
How would your students rate the unit overall?	❑ excellent	❑ good	❑ fair	❑ poor

What would make the unit more useful to you?

Other Comments:

Please fax or mail to: **The NEED Project**
8408 Kao Circle
Manassas, VA 20110
FAX: 1-800-847-1820

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