VIRTUAL LABS

# TEACHER guide Future Power

## Unit

Energy Sources and Transformation

## Topics

- Introduction to Energy Sources
- Fossil Fuel

## Concepts

- Human Use of Energy
- Types and Uses of Fossil Fuels
- Issues of Fossil Fuels

## Inquiry Skills

- Identify questions
- Design investigations
- Gather and interpret data
- Develop explanations
- Evaluate evidence
- Analyze alternative explanations
- Communicate science
- Use math in inquiry

## Time Required

3 or 4 class periods

Both you and your students are encouraged to read the Briefing Document for this Virtual Lab before going to the Explore Lab.

If you are new to Virtual Labs, you should also read the *Virtual Labs Teacher Overview* and your students should read the *Virtual Labs Student Guide* before starting this lab.

## Getting Started

All Virtual Labs pose science problems in a real-world context. In *Future Power,* students investigate the costs of generating electricity with different fuels and under several different scenarios. The lab encourages them to think about the costs and benefits of different energy sources. It can serve as a springboard for a discussion of fossil fuels, renewable and nonrenewable resources, the greenhouse effect, global warming, and environmental policy.

## Intro & Mission

In *Future Power,* students are asked to use their scientific inquiry process skills to solve the following problem:

> Your local power company, LightBright Electric, produces electricity for a small city. They need help deciding what kind of fuel to use to make the electricity. Currently, they use natural gas. Coal is cheaper but it produces carbon dioxide, which contributes to global warming. Natural gas produces less carbon dioxide, but its price is going up.
>
> **The Problem:** Your local power company wants to produce low-cost electricity and control its carbon dioxide ($CO_2$) emissions.
>
> **The Mission:** Figure out which of four fuel options will be best for LightBright Electric: coal alone, a mixture of coal and plant material, natural gas using the company's old technology, or natural gas using a new technology.

## Explore

In the Explore Lab, students investigate the four fuel options by trying them out, one at a time, in a simulated power plant. The simulation allows students to discover: (1) how much fuel is needed to produce a small city's electricity for one day; (2) how much it costs to generate that electricity; and (3) how much $CO_2$ is emitted in the process. The per-day electricity requirements cited are for Berkeley, California, whose population was approximately 103,000 at the time the data was collected.

Investigation in the Explore Lab is open-ended, but students can get some guidance from the Briefing Document, which contains suggested explorations. The teacher's role is primarily one of facilitation. For example, you might take some of the following actions:

- Visit students as they work in the Lab and ask questions about what they are doing.
- Make sure students understand they need to click a fuel more than once in order to light up the city. Encourage them to keep track of the amount of fuel needed to do so.
- Make sure students understand they needn't clear the data board after each fuel test; they can display the data for all four fuel options at once.
- Encourage students to collect their data systematically and to record it on a data sheet.
- Encourage students to think about what effect rising gas prices and $CO_2$ emissions taxes might have on the cost of generating electricity at LightBright.
- Point out the units of measure used in this lab and help students understand them.
  - The unit for coal is "tons," which should be familiar to students.

- The unit for generated electricity is given in "megawatt hours," abbreviated MWh. The M stands for "mega," or "million." 1 megawatt hour = 1 million watt hours = 1,000 kilowatt hours.
- The unit for natural gas is "thousand cubic feet," abbreviated Mcf. This abbreviation may be confusing because this time M does not represent "mega" or "million" but rather "mille," the Latin word for "thousand" (the same M used in Roman numerals).

- Ask students to tell you what they think "biomass" is and explain to you why burning biomass along with coal might reduce the resulting $CO_2$ emissions.
- Find a diagram of the carbon cycle and use it to help students see how extracting and burning fossil fuels increases the amount of $CO_2$ in the natural (short-term) cycle.

Students should leave the Explore Lab knowing that fuels burned in power plants differ in their cost and $CO_2$ emissions. Most students will also understand that some fuels have greater heat efficiency (the amount of fuel it takes to produce a unit of power) than others and that fuels producing the most $CO_2$ will become more costly if a tax is imposed on $CO_2$ emissions. Some students may realize that if LightBright Electric were to switch from natural gas to coal there would be capital costs involved. Encourage those students to investigate these costs and to consider them in making their fuel recommendation to LightBright. Some students may also appreciate that taxing emissions would provide a disincentive to use coal, i.e., it would likely reduce the use of coal for power generation, drive the use of other fuels, and encourage the development and use of more efficient technologies.

## Plan

Next, students write a plan for an experiment that will help them decide which fuel option is the right choice for Light Bright. The plan should reflect what the students have learned in the Explore Lab about fuel costs and $CO_2$ emissions. It should also take into account the possibility that gas prices might rise and emissions taxes might be imposed.

In the Experiment Lab, students can set three different price levels and four different tax rates to see how those variables affect the cost of generating electricity for each of the four fuel options.

Some students may want to know what constitutes a "best" choice. Does "best" mean cheapest? Does "best" mean low emissions? Best in the long term? Best in the short term? Can a "best" decision change over time? Encourage the discussion, but tell students that the choice is theirs to make, and they must explain their choice in their plan.

The plan must include a testable question, a hypothesis, and an experimental procedure. The plan is written offline, and could be completed as homework, but students may want to return to the lab or consult these online resources:

- **The Briefing Document.** This document is essential for student work at all stages of the Virtual Lab, so you may want to print out copies for your students. It can be accessed through either the Mission tab or the Plan tab in the Virtual Lab. The Briefing Document includes a "Carbon Dioxide Emissions Graph," which shows $CO_2$ emissions over 20 years for each of the four fuel options. Encourage your students to use the chart to think about some of the long-term impacts of each fuel option.
- **The Plan Resources,** a collection of articles and/or video clips that can be accessed through the Plan tab in the Virtual Lab.
- **The *Virtual Labs Student Guide,*** which explains what makes a good testable question and how to write a plan.

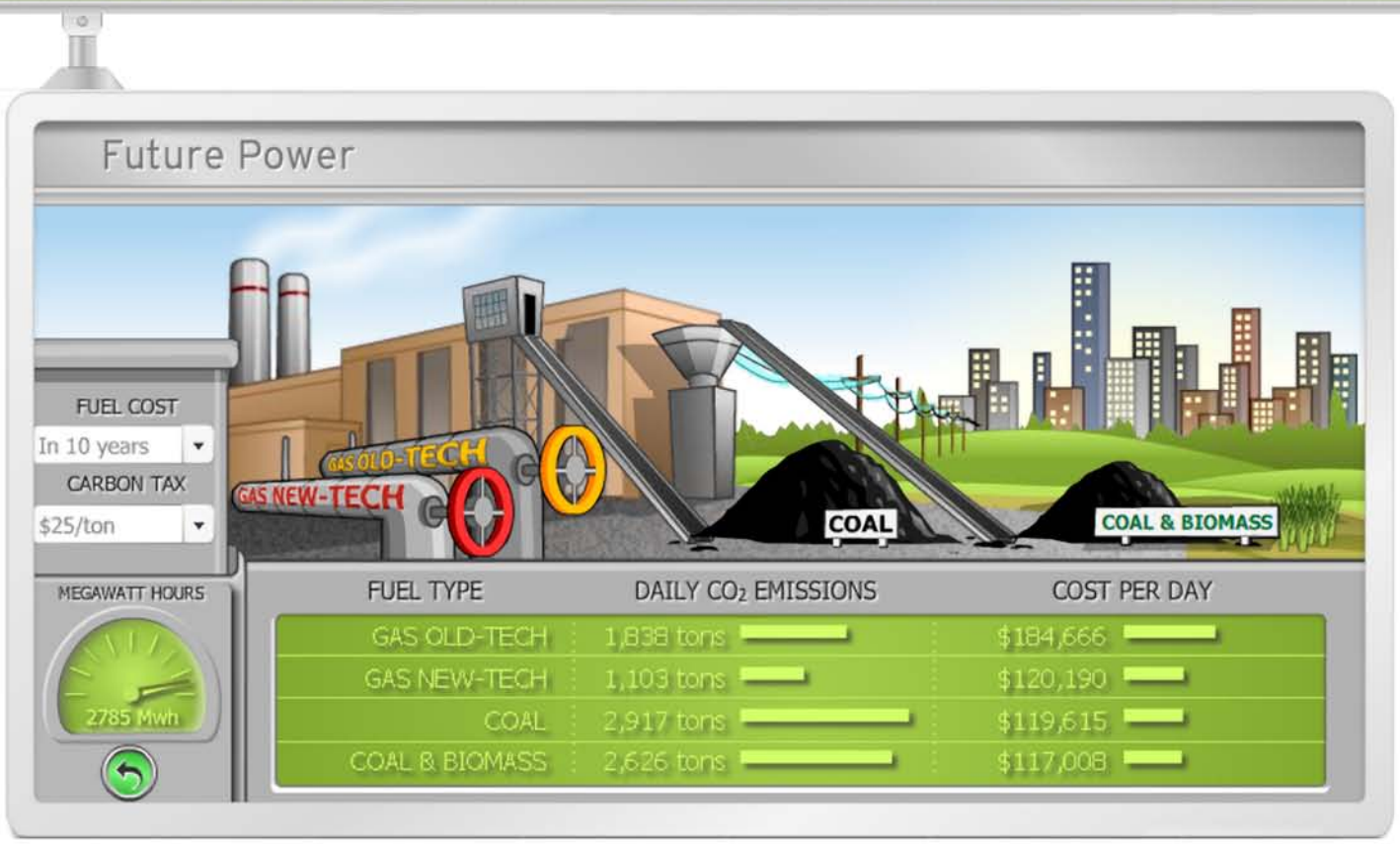
Students will write their plans in their notebooks and bring them to you for approval before they go on to the Experiment Lab. An example of a good plan for *Future Power* is given later in this Teacher Guide. If your students' plans are well conceived, the rest of the Virtual Lab should go smoothly.

## Experiment

In the Experiment Lab, students carry out their plan to investigate and compare the costs of different fuels under different conditions. They should make some record of fuel costs and $CO_2$ emissions in their notebooks or in a data table as they go along. Students may devise their own data sheet, or they may use the Data Table included with this Teacher Guide.

All students should come to understand that the four different fuel options have different costs and benefits. The should also see that changing technology, imposing a tax on emissions, and purchasing fuel in a rising market can all have a dramatic effect on fuel costs.

Students may come to the above understandings — or they may not. At the conclusion of the Experiment Lab, students are asked to write a brief summary of their findings, along with their conclusions and their recommendation to LightBright. You may have to remind them to do so. A sample summary is given later in this Teacher Guide.




There are no "right" answers to this lab. Much depends on the assumptions students make about gas prices and emissions taxes, and some depends on the values students place on cost-effectiveness and environmental protection. Students may come up with different recommendations for different scenarios, or even with recommendations that are contingent on changing circumstances (e.g., "LightBright should stick with natural gas unless prices rise more than predicted and there is no tax on $CO_2$.") What is important is that the students use the Experiment Lab systematically and collect good data, and that they clearly explain their assumptions and their recommendations to LightBright once they have reviewed all the findings.

The teacher's role in the Experiment Lab should be minimal. You should make sure students know how to work the lab, and you can head off any wildly wrong efforts, but otherwise let the experiments run their course. Failure in the lab is OK.

## Collaboration

The Virtual Lab can be done successfully by students working alone or in pairs or small groups. If they collaborate, the students can divide the work according to their skills and interests. One student may feel more comfortable interacting with the screen while another may want to record data. One student may want to lead the small-group discussion while another may want to present the group's results to the class. Of course, the social interaction involved in teamwork has its own value. If your students collaborate in the Virtual Lab, it is up to you to decide whether they should write their experiment plans and summaries separately or together.

## Sharing Results

One goal of the Virtual Lab is for students to act as a community of scientists working together toward the solution of a problem. For this reason, students are asked to share their plans and summaries with their classmates. You may wish to direct this class discussion in one of these ways:

- Discuss any differences in the students' experimental procedures. Ask what kinds of thinking led to their different approaches.
- Discuss any differences in the students' assumptions. Did everyone assume that natural gas prices would continue to rise? Why or why not? What level of emissions tax did students think likely? Ask students what they think might persuade policymakers to decide for or against such a tax.

- Discuss differences in the students' recommendations. How did their assumptions affect the recommendations they made?
- Discuss considerations that are unrelated to the daily cost of the fuel. Did any students consider the environmental impacts of $CO_2$ emissions in making their recommendation? Would power companies such as LightBright consider environmental impacts? Why or why not?

### The Science Behind the Lab: Generating Electricity

Roughly half of the electricity in the United States is produced by burning coal, although the use of natural gas is on the rise and currently accounts for about 17% of electricity production. Renewable energy sources, including hydropower, wind power, and solar power, contribute less than 12% combined. Nuclear power produces about 20%.

The cost of producing electricity from fossil fuels is the result of a complex set of factors including the cost of extracting the fuel, the fuel's availability and cost of delivery, the fuel's heat efficiency (how much output can be produced by a given amount of the fuel), and the costs of complying with environmental regulations. Using more efficient technologies for burning fossil fuels reduces a power plant's daily costs because less fuel is needed to produce the same amount of power; however, upgrading can entail high capital expenditures. The cost data used for this lab are based on figures for the State of Michigan from the U.S. Department of Energy website (a very good resource: www.energy.gov) and were selected to reflect end-cost differences between coal and natural gas for power generation.

As concern grows about the buildup of greenhouse gases in the atmosphere, and as natural gas and coal become more costly to find and deliver, the relative cost of other energy sources will drop. Coal is a "dirtier" fuel than natural gas and the cost of meeting federal requirements for "cleaning" sulfur dioxide, nitrous oxides, and now mercury emissions from coal-burning plant emissions has made natural gas a more competitive choice. A tax on $CO_2$ emissions would make natural gas even more competitive.

## Inquiry and Sample Outcomes

The Virtual Lab gives students the opportunity to use genuine inquiry skills to solve a real-world problem. Students are asked to think of a testable question and a hypothesis, which is a possible answer to that question.

Here are examples of testable questions your students might decide to explore in this Virtual Lab. Of course, your students may think of others.

- How much coal (or natural gas, or coal and biomass mixture) is needed to fuel a small city for one day?
- How does using new technology affect the amount of natural gas required to power a city for one day?
- How high does a tax on $CO_2$ emissions have to be for natural gas to become cheaper than coal?

Here is an example of a fully formed experiment plan:

> Testable Question: If natural gas prices keep rising, can a tax on $CO_2$ make natural gas as cheap as coal?
>
> Hypothesis: A $CO_2$ tax will have to be really high to make gas cheaper than coal because coal is a lot cheaper to begin with.
>
> Procedure: We think prices will keep going up so we will fol low this procedure.
>
> 1. Set gas price to 20 years.
> 2. Set tax to $25.
> 3. Click each of the three fuels (coal and the two natural gas technologies) and record results from the data chart.
> 4. Do again, but this time with tax at $50.
> 5. Do again, but this time with tax at $100.
> 6. Compare all the costs.

Different students will have different plans, and there are many different solutions.

Students are asked to write brief summaries of their experiments, including their results. A summary of one student's experiment for this Virtual Lab might look like this:

> With a tax on $CO_2$ of $25, natural gas using new technology was still a little more expensive than coal. But when we raised the tax to $50, coal was more expensive. So, we were right that the tax has to be pretty high to make coal more expensive than natural gas. We would recommend to LightBright Electric to use coal but maybe mix in biomass to reduce the $CO_2$ that is making things warm up.

Notice that the summary does not include the testable question, the hypothesis, or a detailed description of the student's experimental procedure. Those are in the plan. But the summary should include any conclusions the students have reached.

# DATA table Future Power

Name: _____ Class: _____

| Trial # | Fuel Cost | Carbon Tax | Cost per Day to Power City | | | |
|---|---|---|---|---|---|---|
| | | | Natural Gas/ Old Tech | Natural Gas/ New Tech | Coal | Coal & Biomass |
| 1 | | | | | | |
| 2 | | | | | | |
| 3 | | | | | | |
| 4 | | | | | | |
| 5 | | | | | | |
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VIRTUAL LABS

# BRIEFING document Future Power

## Intro

Your local power company, LightBright Electric, produces elec tricity for a small city. They need help deciding what kind of fuel to use to make the electricity. Currently, they use natural gas. Coal is cheaper but it produces carbon dioxide, which contributes to global warming. Natural gas produces less carbon dioxide, but its price is going up.

What fuel should LightBright use to keep costs low and produce less carbon dioxide?

## Mission

**The Problem:** The Problem: Your local power company wants to produce low-cost electricity and control its carbon dioxide ($CO_2$) emissions.

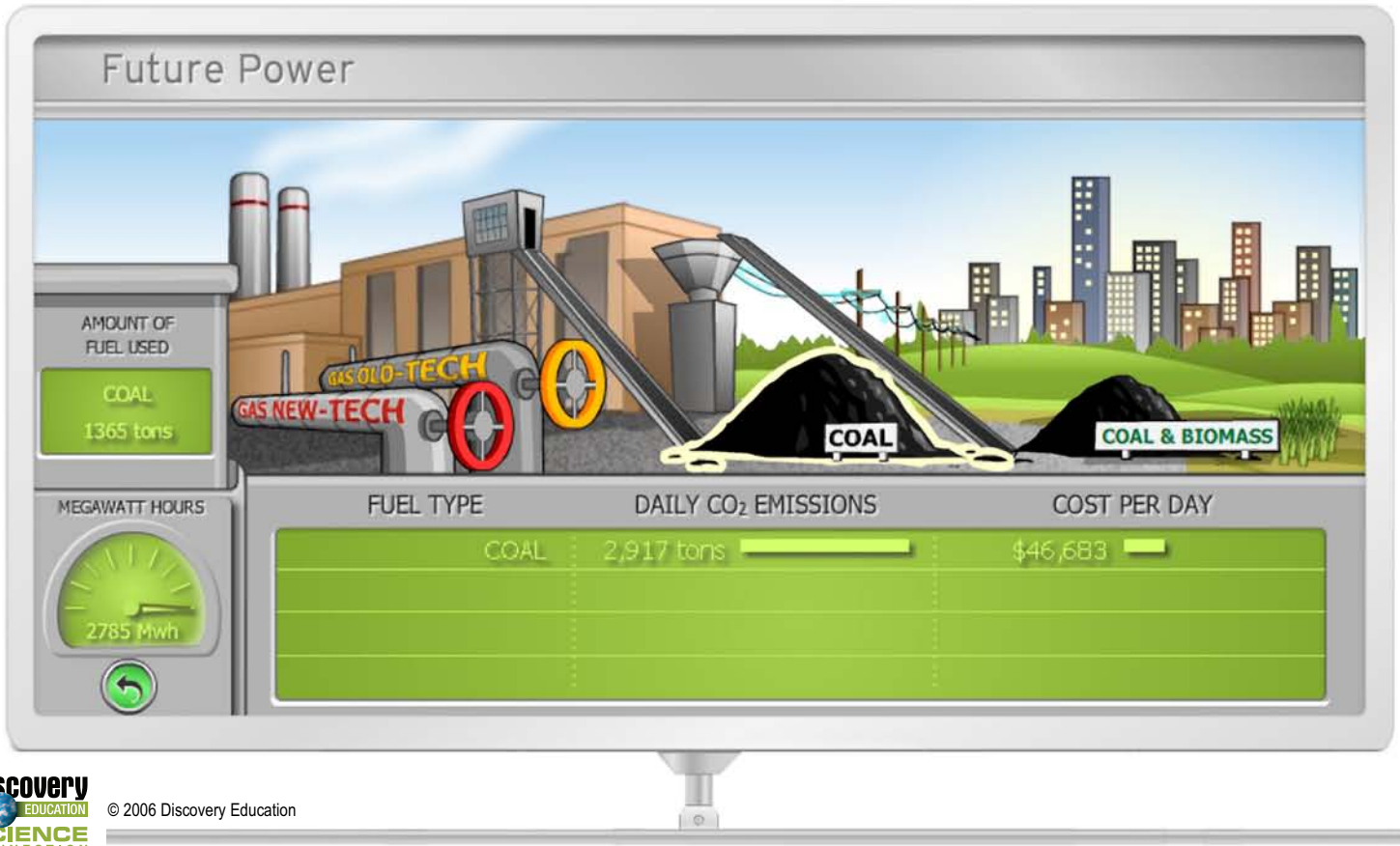
**Your Mission:** Figure out which of four fuel options will be best for LightBright Electric: coal alone, a mixture of coal and plant material, natural gas using the company's old technology, or natural gas using a new technology.

## Explore

First go to the Explore Lab. Here you will find an image of the power plant along with the four fuel options. When you try out the different fuels, you can see how much it costs to light up the city and how much carbon dioxide is produced each day.

Here's how to use the Lab:

- **Gas New-Tech** Click on the valve to use this fuel.
- **Gas Old-Tech** Click on the valve to use this fuel.
- **Coal** Click on the pile of coal to use this fuel.
- **Coal & Biomass** To use this fuel, click on the pile of coal that has the plants growing next to it.
- **Small green window** Displays selected fuel and amount you have burned.
- **Green dial** Displays amount of electricity generated by the type and amount of fuel you have selected.
- **Large green window** Displays $CO_2$ emissions and cost per day for each fuel you use to produce electricity.
- **Reset** The arrow button erases the data in the window.
- **City** The buildings light up when enough fuel has been burned to power the city.



## Suggested Explorations

First, figure out how to light up the city with each of the four fuel options. Then ask a testable question about the different fuels that you can explore in the Explore Lab.

Here's a sample question:

*How does changing the fuel option affect the cost of powering the city for one day?*

Here's a procedure you could use to explore that question:

1. Click on Gas New-Tech until you have powered the city.
2. Click on Gas Old-Tech until you have powered the city.
3. Click on Coal until you have powered the city.
4. Click on Coal & Biomass until you have powered the city.
5. Print or record your results.
6. Compare the daily cost for the four fuel options.

Now ask another question about the different fuels to explore. For example, you might explore the question, "How does adding biomass to coal affect the amount of carbon dioxide produced?" Or, "How does changing the technology affect the amount of natural gas used each day?" You may assume that the new technology is more efficient than the old technology.

As you investigate the different fuels, costs, and emissions, start to think about how the cost of producing electricity might be affected if (1) gas prices go up or if (2) LightBright Electric is required to pay a tax on its $CO_2$ emissions. Both a price increase and an emissions tax could increase the company's fuel costs — and that might affect the company's fuel choice. You will have to take these factors into account when you make your recommendation to LightBright.

Do you have any bright ideas? If you do your explorations systematically and record your results carefully, you should be well on your way to making a good recommendation.

## Plan

Now it is time to plan an experiment that will help you recommend the best fuel choice for LightBright Electric. In the Experiment Lab, you will have the same four fuel options as before, but now you will be able to investigate increasing gas prices and different levels of emissions taxes, too. You will be able to look at current gas prices, prices predicted for 10 years from now, and prices predicted for 20 years from now. You will also be able to look at different tax rates: $25 per ton of emissions, $50 per ton, and $100 per ton. These variables can help you decide the best fuel choice.

But how do you know whether gas prices will *actually* rise and whether an emissions tax will *actually* be imposed? You don't! You will have to make some assumptions and explain them in your plan. And how will you know which fuel choice is "best"? Is the cheapest option always the best choice? You will have to make that decision, too, and explain it in your plan.

If you need help writing the plan, consult the *Virtual Labs Student Guide.* Remember, you can use everything you learned in the Explore Lab, along with information in this Briefing Document. You can also use the Plan Resources, which you will find in the Virtual Lab under "Plan."

Be sure to look at the "Carbon Dioxide Emissions Graph," which shows $CO_2$ emissions over 20 years for each of the four fuel options you are investigating. Use this graph to help you think through the long-term costs and environmental effects of each fuel option. You can find this graph on the last page of this Briefing Document, as well as in the articles section of the Virtual Lab's Plan Resources.

Write your plan in your notebook. Have your teacher approve it before you go to the Experiment Lab.

## Experiment

Go to the Experiment Lab and conduct your experiment. Record everything that happens at each step. You may need to make a chart to keep track of all the data. When you are finished, write a short summary of your experiment, including your results and your recommendations to LightBright Electric.

Did any of your results surprise you? If so, describe them in your summary. Scientists often learn more from unexpected results than from experiments that go exactly "according to plan."

When you have finished your summary, share your plan and your results with your classmates. Did you all start with the same assumptions? Do you come to the same "best choice"?

Whatever the outcome of your individual efforts, together you will have learned some things about the costs and environmental impacts of different fuels that are used to generate electricity. And that is exactly how science gets done: by exploring, asking questions, planning, experimenting, and sharing information with other curious people — like you!

## Some Helpful Information

**Carbon Dioxide ($CO_2$):** Carbon dioxide is a gas that occurs naturally in Earth's atmosphere. You exhale $CO_2$ every time you breathe out. It is also released by volcanoes and by plants and animals when they decompose.

$CO_2$ is also produced whenever fossil fuels — coal, oil, and natural gas — are burned. When fossil fuels are burned, they release large quantities of $CO_2$ into the atmosphere. In fact, in the United States, the burning of fossil fuels to generate electricity is responsible for about 40% of the country's total $CO_2$ emissions.

If $CO_2$ occurs naturally, why worry about it? Many scientists worry that by burning fossil fuels, humans have been releasing too much $CO_2$ into Earth's atmosphere. They worry because $CO_2$ is a greenhouse gas, a gas that traps heat in the atmosphere. On the one hand, this heat-trapping property enables Earth to support life. On the other hand, the steady increase in greenhouse gases due to human activities is believed by many scientists to be causing Earth's temperatures to rise. This temperature rise is called *global warming,* and it may lead to unwanted global changes in Earth's sea levels, weather patterns, landscapes, and ecosystems.

**Carbon Dioxide Emissions Tax:** Concerned about global warming, some governments have decided to impose taxes on $CO_2$ emissions. These taxes charge companies like LightBright a certain amount of money for every ton of carbon dioxide they release into the atmosphere. These taxes make it more costly for the companies to run their businesses, giving them a good reason to develop and use fuels, materials, and processes that emit less $CO_2$.

**Biomass:** *Biomass* is living or recently harvested plant material that can be used for fuel in industrial production. Examples of biomass include grass, corn, and sugarcane. When biomass is burned with coal in power plants, the power plant's overall $CO_2$ emissions are reduced. This is because the carbon from biomass cycles to the atmosphere whether it decomposes naturally or is burned for fuel, so it does not contribute to the build-up of greenhouse gases in the atmosphere.