

Communities and Payments

# Comments for Teachers

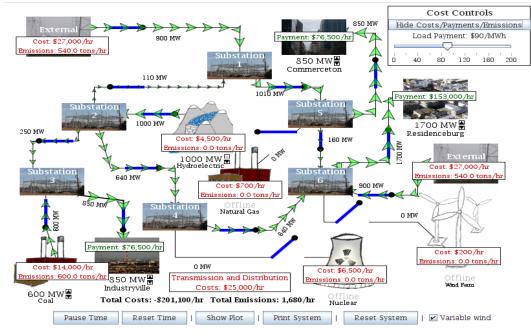
## Power Economics and Emissions

Lesson 1

The applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> shows a simulation of a large scale power system. This applet is an extension of The Power Grid applet <a href="http://tcip.mste.uiuc.edu/applet2.html">http://tcip.mste.uiuc.edu/applet2.html</a>. Generators can be

turned on and off. Transmission lines are green when there is a safe amount of electricity running through them, and a line turns orange when levels exceed 85% of its capacity. When a line capacity is exceeded the line turns red and a blackout occurs if the problem is not addressed by the system manager.

Encourage students to explore the applet. Then use the lessons on the student pages to focus and extend their explorations.



In this applet there is information about Costs and **Emissions** associated with the generators and Payments displayed for each of the communities. Even though a variety of factors determine the expenses associated with providing electricity, the

amounts consumers pay depend on the rate charged by the utility and how much electricity they use and the number of hours they use it. Click on the up or down arrows to change the power demanded by a community. (In this applet a community represents the sum of use by several residences or businesses). The applet then adjusts the community's payment based on the **Load Payment rate**. When the applet opens or the **Reset System** button is pressed, you can see that the **Load Payment slider** shows that the consumers are paying \$90 per megawatt hour (MWh) or \$.09 per kilowatt hour (kWh). Individual utilities set rates for their customers based on their costs. The Load Payment amount can be adjusted using the slider in the **Cost Controls** panel.

## More Resources

• Energy Information Administration - Official Energy Statistics from the U. S. Government. This agency was created by Congress in 1977 to provide unbiased energy information.

http://www.eia.doe.gov/

- Calculate Costs to Use Electricity at Webmath <a href="http://www.webmath.com/kwh.html">http://www.webmath.com/kwh.html</a>
- Find out more about Hoover Dam and hydroelectricity at <a href="http://www.usbr.gov/lc/hooverdam/educate/">http://www.usbr.gov/lc/hooverdam/educate/</a> index.html and <a href="http://www.pbs.org/wgbh/amex/hoover/">http://www.pbs.org/wgbh/amex/hoover/</a>





#### Lesson 1

## Power Economics and Emissions

Use the applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> to explore some of the economics of generating and using electricity. In the applet there are five different types of generators delivering electricity to three communities. You can see the total payments per hour for each of

the communities and the costs and emissions per hour for each of the generators.

1. Adjust the amount of electricity each of the communities is demanding. What else can you change?



Payment: \$17,000/hr

#### MW and MWh

Notice that the power produced by the generators and demanded by the communities is measured in MW. This measure of power does not consider time. You could think of it as the production of the generator at one instant. When energy is sold or purchased, the price depends on the amount of power used per hour and can be measured in MWh. These units (MW and MWh) measure large amounts of power and energy. When you purchase energy for your home it is measured in kWh. 1000 kWh equals 1 MWh.

Electricity is generated at power plants and then delivered to homes, businesses and industry. The entire system of transmission lines, substations and transformers is known as the power grid.

When the applet opens or you press the **Reset System** button, the communities are paying \$90

per megawatt per hour (MWh) for the electricity they are using. The amount a customer pays depends on the rate charged, the amount of power used, and the number of hours it is used.

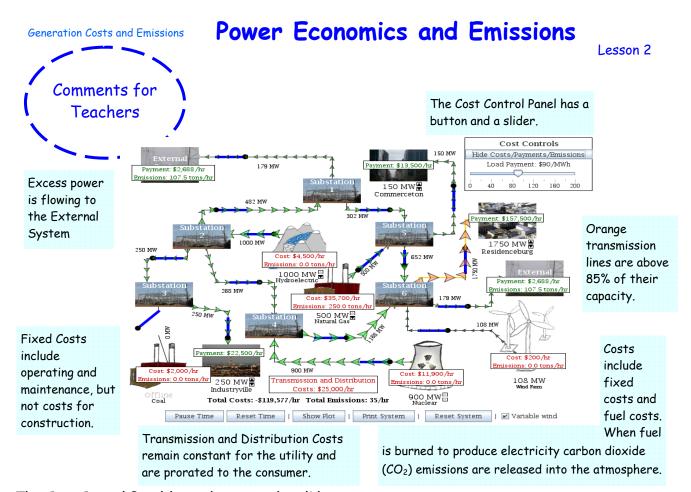
Notice the power demand from the three communities.

Residenceburg is demanding 1,700 MW; Commerceton, 850 MW; and Industryville, 850 MW. These three locations are the consumers of the electricity. That is, they are the customers that purchase power from the system.

- 2. How much are the total payments to the power producers from Industryville, Commerceton, and Residenceburg each hour?
- 3. Click on the up or down arrow under the Commerceton Commerceton image to change the demand for electricity from this community. What happens when you click the up arrow? What happens when you click the down arrow?
- 4. How much is Commerceton's payment per hour when the MW demand is 500 MW?
- 5. What happens when you increase the demand from Residenceburg to 2000 MW? What about 2050 MW?







#### The Cost Control Panel has a button and a slider.

- The button will hide or display the Payment boxes and the Costs and Emissions boxes shown on the applet. These are the white boxes shown on each consumer or generator of electricity. For each generator these boxes tell the amount of emissions of  $CO_2$  per hour the generator is producing, and the cost of operation per hour in dollars. These emissions and cost amounts change when the MW output of the plant changes. For each of the three consumers of electricity payment per hour is shown. This payment changes as the consumers' MW demand varies.
- The slider will allow the Power Grid operator to change the amount the utility charges consumers for the electricity produced by the system. When the applet opens it charges \$90/MWh.

#### Costs and Emissions are shown for each generator.

 Carbon dioxide is produced when fossil fuels are burned. Carbon emissions from the Coal and Natural Gas generators are increased as the power each produces increases.

#### Fixed Costs

When any of the generators are not online, they still have costs. These costs include the operation
and maintenance of the generators even when they are not producing electricity. Examples of
these expenses would include such costs as employees' wages, costs associated with buildings, state
and local taxes, the cost of insurance, and the cost to maintain the

#### More Resources

- EIA Electricity InfoCard 2007 <a href="http://www.eia.doe.gov/bookshelf/brochures/electricityinfocard/elecinfocard2007/elecinfocard.html">http://www.eia.doe.gov/bookshelf/brochures/electricityinfocard/elecinfocard2007/elecinfocard.html</a>
- A virtual power plant tour is provided by Salt River Project Power District http://www.srpnet.com/education/tour/

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equipment.

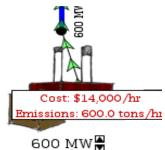




When the applet at http://tcip.mste.uiuc.edu/applet3.html opens or the Reset System button is clicked, two generators are producing electricity and the coal generator is producing carbon dioxide emissions. There are costs and emissions associated with the power from the external system. We do not always know the source of this power so the applet uses an average based on representative generation types for the U.S.

- 1. The applet shows costs and emissions information for each generator. Click the up and down arrows under the generators to change the production. What else changes.?
- 2. Complete the chart below using information from the coal generator.

How do the costs and emissions increase with the increase in power production?



600 MW

A power company incurs a variety of costs. All of these costs are reflected in the price consumers pay for electricity. Fuel costs vary depending on the type and availability of the fuel. There are transmission and distribution expenses associated with delivering the electricity from the generator to the consumers. There are also fixed costs or operating and maintenance costs. Even if a generator is not producing electricity, the machinery has to be maintained and the workers have to be paid. There are costs associated with the buildings owned by the company, costs associated with new construction and taxes. Power companies incorporate these expenses into a per kilowatt hour (kWh) rate that helps determine the price they charge their customers.

Coal Generator Costs and Emissions					
Power produced (MW)	Costs (\$ per hour)	CO <sub>2</sub> emissions (tons per hour)			
0					
300					
400					
500					
600					
700					

3. Switch the coal generator offline. What are the costs and emissions now?

When a generator is offline, there are no emissions or fuel costs, but there are still fixed costs associated with operating and maintaining the generator.

4.	What	are	the	fixed	costs	for	each	generato	r?
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Coal	Natural gas	Hydropower	
Wind	Nuclear		





#### **Payments**

## Power Economics and Emissions

Lesson 3



Use the applet at http://tcip.mste.uiuc.edu/applet3.html and sample power bills to explore some of the factors that determine the price of electricity. This family used 2989 kWh of electricity during this summer

Total kWh	08/13/2008	2989.0000	Summer kWh	08/13/2008	2989.0000	
		ELE	CTRIC SERVICE BILLING DETAIL			
DS - Reside	ntial (DS-1)	Sei	rvice From 07/17/2008 to 08/13/2008	3		
Former Space	ce Ht Acct 15l	k And Over				
· ·	Customer C	harge			\$6.29	
	Meter Charg	je -			\$3.62	
		Deliv Chg Summe	r 2,989.00 kWh @ \$.03203	000	\$95.74	
	Electric Envi	ironmental Adj	2,989.00 kWh @ \$.00081	680	\$2.44	
	Instrument F	unding Charge	2,989.00 kWh @ \$.00690	000	\$20.62	
		unding Credit			\$20.62	
	Rider EDR (		2,989.00 kWh @ \$.00037	859	\$1.13	
	Total Delive	ry Service Amount				\$109.22
Electric Sup	oly (BGS-1)	Sei	rvice From 07/17/2008 to 08/13/2008	}		
	Purch Elec S	Summer	2,989.00 kWh @ \$.06385	000	\$190.85	
	Market Value	e Adi	2,989.00 kWh @ \$.00150	110	\$4.49	
		Supply Cost Adj	2,989.00 kWh @ \$.00070	000	\$2.09	
	Transmissio	n Service Charge	2,989.00 kWh @ \$.00318	000	\$9.51	
	Total Supply	/ Amount				\$206.94
Taxes			Service From 07/17/2008	to 08/13/2008	3	
	Illinois State	Electricity Excise	Tax		\$9.75	
		elated Charges			•	\$9.75
Total Electr	ic Charges				\$325.91	

month. Notice that there are three major billing categories. The total delivery service amount is \$109, 22, the electric supply total is \$206.94 and the tax total is \$9.75.

The delivery charge is about \$0.037 per kWh. This includes the charge for the wires that carry electricity and the meter and transformer pole or box near the house. These charges vary greatly from region to region. In the applet they are included in the Transmission and Distribution Costs.

The electric supply charge is about \$0.069 per kWh. This is the type of charge that is shown in the applet as payment from the communities. Remember, this is a bill for one month for just one family, and the community payment in the applet is for a large neighborhood. The electric supply cost varies from month to month.

At the right is a bill for the

Total kWh 02/14/2008 6153.0000 02/14/2008 6153.0000 Non-Summer kWh ELECTRIC SERVICE BILLING DETAIL DS - Residential (DS-1) Service From 01/15/2008 to 02/14/2008 Former Space Ht Acct 15k And Over Customer Charge Meter Charge Distribution Deliv Chg Non-Summer \$3.62 6,153.00 kWh @ \$.01998000 \$122.94 Electric Environmental Adj 6,153.00 kWh @ \$.00096420 \$5.93 6.153.00 kWh @ \$.00670000 Instrument Funding Charge \$41 23 Instrument Funding Credit Total Delivery Service Amount \$138.79 Service From 01/15/2008 to 02/14/2008 Electric Supply (BGS-1) Non-Summer (0-800 kWh) Non-Summer (Over 800 kWh) 800.00 kWh @ \$.07957000 5,353.00 kWh @ \$.01024000 \$63.66 \$54.81 6,153.00 kWh @ \$.00004400 6,153.00 kWh @ \$.00074000 Market Value Adj \$0.27 Supply Cost Adj \$4.55 6,153.00 kWh @ \$.00247000 Transmission Service Charge Total Supply Amount \$138.49 Service From 01/15/2008 to 02/14/2008 Taxes Illinois State Electricity Excise Tax \$19.85 Total Tax Related Charges \$19.85 **Total Electric Charges** \$297.13

same family, but for a month during a Mid-West winter. This family uses electricity for heat. Even though they use more kWh of energy during this month, their electric bill is less. What else do you notice when you compare the two bills?

#### More Resources

- Check the website for your local power utility for sample power bills and information about them
- Ameren Illinois Residential Customer Bill Sample. http://www.ameren.com/residential/ adc\_AmerenILBillDescriptions.asp
- Residential rate information from Sacramento Municipal Utility District. This utility uses a tiered rate system to encourage conservation. It also offers a voluntary program to users designed to lower demand during peak times.

http://www.smud.org/en/residential/rates/Pages/rates.aspx

• Xcel Energy's energy plans and rates vary from state to state.

http://www.xcelenergy.com/Company/About Energy and Rates/Pages/Temp.aspx





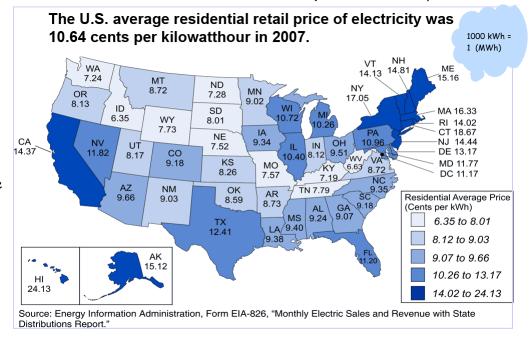
Use the applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> to explore some of the factors associated with the price of electricity. When the applet opens or you press the Reset System button the Load Payment slider is set at \$90/MWh.

1. What changes when you move the slider?

This map of the United States shows average residential retail prices in 2007, in cents per kWh of electricity for the entire U.S. and for individual states. Move the **Load Payment** slider to represent

the U.S. average. Round to the nearest whole dollar per MWh .

2. If one million people in Residenceburg each use an amount of electricity equal to two 100 watt light bulbs, the demand from the community is 200 MW. What is the per hour payment from Residenceburg for this electricity?



- 3. If Residenceburg is in MN, then what is the payment from Residenceburg if the demand is 1000 MW?
- 4. Move the **Load Payment** slider to represent the retail price of electricity in your state. What is the payment for Residenceburg if the demand is 1800 MW?
- 5. Which state has the highest price for electricity? Which has the lowest? Why do you think the states' rates vary so much?
- 6. Utilities may have different rates for their business and industrial customers and may also vary their rates with the season. Look at some sample utility bills to learn about load payments. You may be able to get sample bills and guideline about how to read them from your local electric utility.



Lesson 4

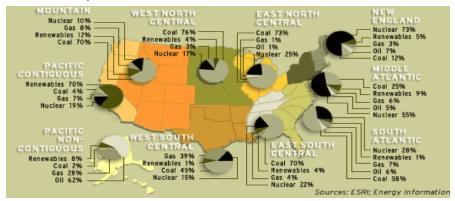
Comments for Teachers

The applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> is an example of a vertically integrated power system. This utility owns the generator plants and the transmission and distribution systems. In the applet transmission and distribution, fixed costs, and fuel cost rates

remain constant. The user can adjust the Load Payments, demand from the communities and the

power produced by the generators.

Costs to produce electricity frequently change. Fuel sources and constantly changing demand are just two influences on the cost. Fuel availability and costs vary from region to region. Hydropower is plentiful in the Northwest, and New England uses more nuclear power. More electricity is often needed in the afternoon and early evening hours. There is also a seasonal



This map shows sources of electricity for regions of the U. S. Renewables might include hydropower, wind, solar and biofuels.

demand in most states for more electricity in the summer when air conditioners are used.

Utilities prepare for changes in demand by using both base load and peak load generators. Base load generators are usually more efficient and are able to produce a consistent supply of power. Peak load generators are usually more expensive to operate, and are generally used to meet demands during "peak" or high use times. Their production can be changed quickly. In the applet the natural gas generator is a peak load generator. Hydroelectric generators use moving water to spin a turbine. Often, water is collected in a reservoir created by a dam and then released to flow through the turbine. Because they are efficient and easily controlled they are used for both base load and peak load.

In some areas consumers can choose a time of use plan that charges for electricity at two or more rates, a lower rate for using electricity during off-peak hours and a higher rate for on-peak times. Those consumers who can shift some of their use to off-peak times save money for themselves and for the power utility.

Transmission and distribution costs are all of those associated with getting the electricity from the generator to the user. Transmission and distribution is the "highway" for electricity. It includes

many sizes of wires, power poles, substations, transformers and meters.

#### More Resources

- Generating Capability/Capacity (EIA)
  - http://www.eia.doe.gov/cneaf/electricity/page/prim2/chapter2.html
- Central Iowa Power Cooperative's Fundamentals of Electricity
  - http://cipco.apogee.net/foe/home.asp
- State Energy Profiles http://tonto.eia.doe.gov/state/index.cfm

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Costs and Charges

# Power Economics and Emissions

When the applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> opens or the Reset System button is pressed, two generators are producing electricity and three are not.

l. How much power is each gei	nerator producing? Coal	Natural gas
-lydropower	Wind	Nuclear
2. How much is the total power 3. How much total power are t	Nuclear 10% Nuclea	
the communities are demandin	not producing as much power as g, the system needs to import cm. How much power is the ex-	PACIFIC NON THE CONTRACT OF TH
5. How much are the supply co	osts per hour (generator and exter	nal system)?
, , ,	Hydropower	·
Nuclear External s		
The applet simulates a system that is owned by a power utility company. The company provides power to three communities. It owns and operates five types of generators and the transmission lines that serve the communities. On this system, it is usually possible for the utility company to supply all of the load demand using the local generators.	the producer spending altogether to provide power to these three lo 8. Are the power provider's costs	costs? That is, how much per hour is (including the external system costs) ocations?s more or less than the payments How much is the provider's profit on the nuclear power plant?
However, there could be many reasons why this is not possible or most profitable, and then electricity is	How much is the provider's profit  11. Without changing the demand provider's profits. How much is the second seco	from the communities, maximize the ne provider's profit?



the external system.



Lesson 4

Lesson 5

Comments for Teachers

Types of Generation

The applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> is an example of a vertically integrated electric power system. The generators and the

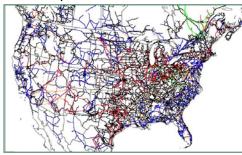
Power Generation, Transmission, and Distribution
Transmission Lines
Carry Electricity Long Distances Power Plant Distribution Lines Generates Electricity Carry Electricity To Houses Neighborhood Transformer Transformers On Poles Step Steps Up Voltage Transformer Steps Down Voltage Down Electricity Before It For Transmission Enters Houses

Source: Energy Information Administration

interconnected system. Using the applet is like operating the dispatch center, and the external system in the applet represents connections to the interconnected system.

Today nearly all power utilities in the United States belong to one of three major power grid networks, the Eastern Interconnected

users are connected by the transmission and distribution network. Dispatch centers communicate with the generators and are also authorized to buy and sell electricity to others within the



Transmission in the Contiguous United States

System, the Western Interconnected System or the Texas Interconnected System. Regional entities within each interconnected system help power utilities coordinate their supplies and buy and sell from each other.

Electricity travels at near the speed of light through the "path of least resistance." Its flow can only be controlled by opening and closing switches. Currently, there is no large scale storage of electricity. It must be produced as it is consumed. So power producers need to respond to the varying demand of their customers 24 hours a day.

As demand for electricity increased, local utility systems realized there were economic advantages and increased reliability with interconnection. The system we call the power grid grew out of these needs over several years. Regional Transmission Organizations (RTO's), Independent System Operators (ISO's), and local control area operators all work to keep the generation and transmission of electricity reliable and economical.

The North American Electric Reliability Corporation (NERC) was founded in 1968 by the electric utility industry. It is an independent not-for-profit organization that works with utilities in Canada,

the U.S. and northern Mexico to make the electric generation and transmission system safe and reliable.

#### More Resources

- North American Electric Reliability Corporation <a href="http://www.nerc.com/">http://www.nerc.com/</a>
- •U.S. Department of Energy; Office of Electricity Delivery and Energy Reliability http://www.oe.energy.gov/index.htm





Lesson 5

Use the applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> to explore how systems of electricity are interconnected. When the applet opens or you press the **Reset System** button, Residenceburg is using 1,700 MW per hour, Commerceton is using 850 MW per hour, and Industryville is using 850 MW per hour.

- 1. What happens to the External System cost when each of these three locations increases the amount of power they need?
- 2. What could cause each of these locations to have to increase the amount of energy they need?
- 3. What could cause each of these locations to have a decrease in the amount of energy they need?
- 4. Press the **Reset System** button. Currently, the system is spending \$54,000 to purchase energy from external systems. Can you find a way to set the system so that the power grid does not have to rely on external systems to meet the needs of its customers?

Power Source	Cost of operation (dollars per hour)	Amount of CO <sub>2</sub> Emissions (tons per hour)	On-line or Off-line?	Output (MW)
Coal				
Nuclear				
Wind				
Hydroelectric				
Natural Gas				
External Systems				

Energy Demand (MW)

Residencebuly		
Commerceton		
Industryville	Transformer Steps Up Voltage For Transmission	Neighborhood Transformer Transformers On Poles Step Steps Down Voltage Down Electricity Before It Enters Houses
Dollars received from customers		Source: Energy Information Administration
Expense to provide power to customers (Be sure to include the transmission and distribution costs!)		



Total Emissions/hour

Customers

Desidencehura

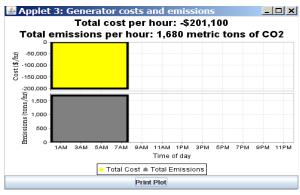


Comments for Teachers

Lesson 6

Use the plot with the applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> to explore some of the economics of generating and using electricity. When the applet opens the system is operating at a profit to the power utility. Press the **Show Plot** button to see a plot like the one below.

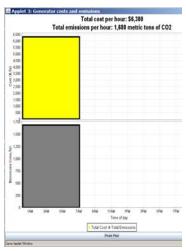
This plot displays two separate pieces of information that change over time as the setting of the grid change. The yellow section of the plot shows the total cost per hour of producing electricity for the power utility. When the cost is positive, the utility is paying more for fuel and for its operating costs than the payments from the communities. If the costs are positive the utility is losing money. If the cost is zero, the communities are paying the utility exactly enough to equal the utility's expenses. If the cost is negative, the utility's expenses are less than the payments and it is making a profit.



Notice the load payment is \$90/MWh and there is a negative cost (-\$201,900 per hour) to provide power to the customers of this utility. This amount comes from subtracting the costs of running all

the generators and the transmission and distribution costs from the total payments received from the three consumers of electricity. At this load payment rate the utility's costs are negative and it is making a profit. It will show a loss, or positive cost, if the power utility takes in less money than it is spending. For example, reset the system and change the Load Payment Slider to \$30MWh. Turn on the Natural Gas generator. Display the plot and it now shows a loss of \$6,300. It is shown as a positive on the plot because the plot shows cost and the \$6,300 is the amount of cost that is more than the revenue.

The gray part of the graph shows the amount of emissions for the Power Grid. Notice that the emissions shown in this plot are from the Coal generator and the External System. Emissions come from burning fossil fuels. If the Natural Gas generator is online it too produces  ${\it CO}_2$  emissions.



Many power utilities have carbon offset programs that involve planting

trees. These include large and urban forestry projects. "Eighteen electric utilities, reported 32 urban forestry projects for 2004. For the 32 projects, reported sequestration totaled 20,000 MTCO $_2$  Urban forestry projects are unique in that, under some circumstances, they can reduce energy consumption as well as sequester carbon. Shade trees planted near buildings reduce summer air condition-

## More Resources

ing requirements; in addition, trees can act as windbreaks, reducing heating needs in the winter" (EIA Carbon Sequestration).

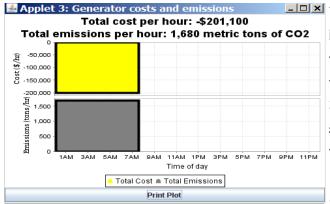
- Energy Information Agency publications
  - http://www.eia.doe.gov/oiaf/1605/archive/vr04data/chapter4.html
- Renewable Resource Data Center at the National Renewable Energy Lab http://www.nrel.gov/rredc/

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1. Use the applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> to explore some of the economics of generating and using electricity. Press the Reset System button, then press the Reset Time button and the Show Plot button. Let the system run until the graph shows several hours. Press Pause Time. You should see a plot that looks like the one below. What does it show?

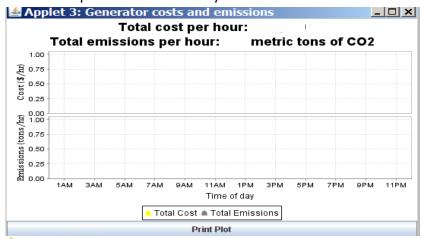


The yellow part of the graph shows the cost per hour to the utility. When the cost is negative, the utility's costs are less than the payments from the communities and it is making a profit.

- 2. How much profit per hour does the graph show for the utility? \_\_\_\_\_ Is this the same as you calculated in lesson 4? \_\_\_\_\_
- 3. The grey part of the graph shows the carbon

dioxide ( $CO_2$ ) emissions produced per hour. How much  $CO_2$  is the system producing? \_\_\_\_

- 4. These plots show costs and emissions for about eight hours. During that time period how much profit did the utility make? \_\_\_\_\_ and how many metric tons of  $CO_2$  were released into the atmosphere? \_\_\_\_\_ Why are we concerned about both costs and emissions?
- 5. Press the **Reset Time** button. Keep the power demand from Residenceburg at 1700 MW and from Commerceton and Industryville at 850 MW. Adjust the system so that the utility is making a profit and the  $CO_2$  emissions are lower than 1000 metric tons per hour, then click the **Show Plot** button, and let the system run until the graph shows several hours. Then press **Pause Time**. Shade this plot to look like what you see.



6. How much power and  $CO_2$  are each of the generators producing?

Coal \_\_\_\_\_\_

Hydro \_\_\_\_\_

Wind \_\_\_\_\_

Nuclear \_\_\_\_\_

Natural Gas \_\_\_\_\_\_

External System \_\_\_





Lesson 7

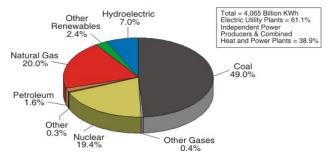
Comments for Teachers

Among the gases emitted during the burning of fossil fuels are sulfur dioxide ( $SO_2$ ), nitrogen oxides ( $NO_x$ ), and carbon dioxide ( $CO_2$ ). Only  $CO_2$  emissions are shown in this applet. Sulfur dioxide and nitrogen oxides cause acid rain. There are ways of reducing these emissions

which can reduce their effects. Electric generators can use coal that contains less sulfur, wash the coal, or use scrubbers. Scrubbers chemically remove  $SO_2$  from gases that leave smokestacks.

However, all these options increase the cost to produce electricity.

 $CO_2$  is a major contributor to the increase of greenhouse gases. Greenhouse gases allow sunlight to enter our atmosphere. Then when the sunlight reflects off the surface the gases hold heat in our atmosphere. Without greenhouse gases the earth would be too cold, but too much  $CO_2$  production is causing the temperature of our atmosphere to rise



This graph shows that the majority of electricity generation in the United States is from coal and natural gas.

too much. When coal, oil, or natural gas are burned they produce greenhouse gases. Fossil fuels are made of hydrogen and carbon. The carbon combines with oxygen to release carbon dioxide when these fuels are burned. Burning natural gas releases about one half of the amount of carbon dioxide as burning coal. Burning oil releases about three-fourth the amount. Using fossil fuels or biofuels to produce electricity, heat our homes and businesses or operate our vehicles increases the amount of  $CO_2$  in the atmosphere.

Deforestation also increases the amount of carbon dioxide in the air. Forests offset human produced carbon emissions through photosynthesis. The amount of carbon absorbed depends on the size of the tree. A large sugar maple can remove 450 pounds of carbon dioxide in a year. At that rate 31 trees per operating automobile in the United States would offset all U.S. automobile-related carbon dioxide emissions.

Energy experts recognize the importance of reducing the production of harmful gases, but also want to keep energy costs low. Using the applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> demonstrates aspects of balancing costs and emissions while meeting consumer demand. Legal authority for energy policy belongs to individual states. Some states require electricity producers to use renewable sources for specified percentages of their power production and many states also have guidelines for reductions of greenhouse gas emissions.

#### More Resources

- U.S. Environmental Protection Agency Climate Change <a href="http://www.epa.gov/climatechange/">http://www.epa.gov/climatechange/</a>
- EPA's website, Climate Change for Kids, has information about green house gases and climate change for teachers and students <a href="http://epa.gov/climatechange/kids/">http://epa.gov/climatechange/kids/</a>
- State-specific information from the U.S. Department of Energy's (DOE's) Office of Energy Efficiency and Renewable Energy (EERE) <a href="http://apps1.eere.energy.gov/states/state\_information.cfm">http://apps1.eere.energy.gov/states/state\_information.cfm</a>
- Information about acid rain http://www.policyalmanac.org/environment/archive/acid\_rain.shtml

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Use the applet at <a href="http://tcip.mste.uiuc.edu/applet3.html">http://tcip.mste.uiuc.edu/applet3.html</a> to explore carbon dioxide emissions produced when generating electricity. Press the **Reset System** button.

Then turn on the Natural Gas, Nuclear and Wind Generators so all of the generators are producing.

- 1. Look at the Coal Generator. Notice the Coal Generator power output is 600MW and it has carbon dioxide emissions of 600 tons per hour. Change the amount of power produced. How do the emissions change?
- 2. The emissions shown in this applet are carbon dioxide ( $CO_2$ ) emissions. Carbon dioxide is a greenhouse gas. Which generators produce  $CO_2$  emissions?

Among the gases emitted during the burning of fossil fuels are sulfur dioxide (SO2), nitrogen oxides ( $NO_x$ ), and carbon dioxide (CO2). Sulfur dioxide and nitrogen oxides cause acid rain. There are ways of reducing these emissions which reduce acid rain. For example, generators could use types of coal that contains less sulfur. wash the coal, or use scrubbers. Scrubbers chemically remove SO<sub>2</sub> from gases that leave smokestacks. However, all these options increase the cost to produce electricity. Carbon dioxide is a greenhouse gas. Greenhouse gases allow the

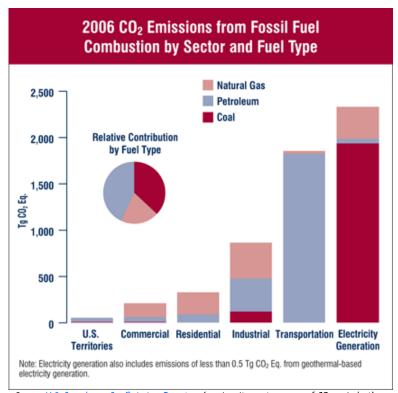
Earth's atmosphere and then trap some of this heat causing the Earth's temperature to rise. Without greenhouse gases the Earth would be too cold for human life, but in recent years the amount of greenhouse gases in the atmosphere has been increasing and the temperature of the Earth is rising. Scientists are concerned that even a small increase in the

global temperature could have

serious consequences.

sun's energy to enter the

- 3. How do the emissions for the Coal Generator compare to the emissions for the each of the other generators?
- 4. How do the emissions change as the power production changes?
- 5. This graph shows sources of  $CO_2$  emissions for the United States in 2006. What information does the graph give you?



Source:  $\underline{U.5.}$  Greenhouse Gas Emissions Inventory (y-axis units are teragrams of  $CO_2$  equivalent). Read more at:  $\underline{\text{http://www.policyalmanac.org/environment/archive/acid\_rain.shtml}}$ .







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http://tcip.mste.uiuc.edu/

