

Baseload Balance

🕒 Background

Most students don't give electric power much thought until the power goes out. Electricity plays a giant role in our day-to-day lives. This activity demonstrates how electricity supply is transmitted on the electric grid to consumers. It also encourages students to explore the differences between baseload and peak demand power and how power companies maintain supply to ensure customers have power as they need it.

You will lead your students through a hypothetical day, consisting of morning, all day, evening and night. As the time of day changes, students are encouraged to think about how their energy use changes. Jumbo paper clips are used to represent power demand and power generation. A simple, double-pan balance is used to show how demand for electricity is balanced with generation.

🎯 Objectives

Students will be able to:

- Explain how demand for electricity changes throughout the day;
- List energy sources used for baseload generation and those that can be used for peak demand.

📄 OEP Provided Materials

- Hanging balance

✓ Preparation

- In this activity a jumbo paper clip will represent 5 MW of demand or generation. You may choose to designate one color for baseload generation, one color for baseload demand, one color for peak generation and one color for peak demand.
- Cut apart *Baseload Balance Placards* and fold them on the dotted line to make tent-style labels that stand up. Place one near each side of the double balance.
- Cut apart *Peak Demand and Generation Cards*.

✓ Procedure

1. Review key terms for student understanding, which are:
 - *Demand* - our desire for electricity exactly when we want it.
 - *Load* - the amount of electricity we pull from the grid.
 - *Generation* - the amount of electricity that power plants produce.
 - *Baseload demand or generation* - electricity use or production at all times of the day or night, all year long.
 - *Peak demand or generation* - electricity use or production that varies at different times of the day or night and different times of year.
2. Review the *Baseload Balance Student Information* with the class.
3. Project the *Baseload Balance Generation Parameters* sheet. Discuss why coal and nuclear are used for baseload generation. These two fuels take 24 hours to reach full capacity, so they are up and running and readily available.
4. Distribute the *Peak Demand and Generation Cards* to students. Have them gather as many paperclips as they need.
5. Place the balance on the demonstration table. Place the "Demand" placard on one side of the balance and the "Generation" placard on the other side.

6. Say, "Our society uses electricity all day and night. Our refrigerators run, hospitals take care of people, and factories produce goods. Our baseload demand is 115 MW. Place 115 MW on the demand side." Note: If one paperclip equals 5 MW, you will be placing 23 on the Demand side.
7. Say, "All night and day, power plants produce electricity. What type of fuel is typically used to produce this power? (Coal, Nuclear and Natural Gas) Place 115 MW on the Generation side." The pans should now be balanced.
8. Utility companies strive for this balance. They are careful to make only as much electricity as we will use. If they produce more electricity than needed, the energy is wasted and usually cannot be stored. If they don't produce enough, there could be blackouts.
9. Say, "It is now 7:00 in the morning and people are getting up to start their day. Who has morning peak demand?" As this student comes to the table, ask students to think of things they use in the morning that need electricity. When the student places the paperclips in the pan, the balance should tip toward Demand.
10. Say, "What will the power company do now?" Instruct students with generation cards to share their cards with the group. Ask students to come to a consensus about what peak power source(s) should be utilized to balance the scale.
11. The student with the generation cards to meet morning demand should place their paperclips on the Generation side. The pans should now be balanced.
12. Say, "Utilities try to make sure they spend as little as possible while meeting demand. This way they don't have to bill customers more in the future. Morning demand begins at 6:00 and lasts until 10:00 am. How much money did it cost to meet the morning demand? Remember the card shows cost of the megawatt per hour. Do you wish to change the sources you used?" Allow students to discuss and make adjustments if desired.
13. Say, "Some things are turned on and run all day long like lights and computers at schools and businesses. Who has All Day Demand?" Have the student come forward and ask students what types of devices we use all day that require electricity. The All Day Demand student should place the correct number of paperclips on the Demand side.
14. Say, "What will the power company do now?" Instruct students with generation cards to share their cards with the group. Ask students to come to a consensus about what peak power source(s) should be utilized to balance the scale.
15. Say, "It is now 5:00 and the end of the day. School is over and offices are closing and people are going home for the day. What do we need in the demand pan? (Remove morning demand and generation)
16. Say, "Are there any other adjustments we need to make? Does someone have the card that says, Evening Peak Demand?" As the student comes forward, ask students what types of devices we use in the evening but not during the day. Ask students to compare the evening demand with the all-day demand. As the Evening Peak Demand student lays the paperclips in the Demand pan observe the imbalance.
17. Say, "What about generation? What will happen to the sources you have chosen to use to generate power during the day? Is there a better source of power for Evening Peak Demand?" Allow students to adjust their power sources so the pans are balanced.
18. Finally say, "It is now 11:00 pm and everyone is in bed or will be in bed very soon. We are back to baseload demand and generation. Remove all the peak demand weights and generation weights, returning to the 115 MW of baseload demand and generation.

Extension

Check out Ohio's Regional Transmission Organization's , PJM, website at www.pjm.com. There you will find relevant videos, forecasts, interactive charts, and more to share with your class.

Baseload Balance Student Information

Introduction

Four kinds of power plants produce most of the electricity in the United States: coal, natural gas, nuclear, and hydropower. Coal plants generate about 33 percent of the electricity we use. There are also wind, geothermal, waste-to-energy, solar, and petroleum power plants, which together generate a little less than ten percent of the electricity produced in the United States. All of this electricity is transmitted to customers via the network of transmission lines we call the grid.

Fossil Fuel Power Plants

Fossil fuel plants burn coal, natural gas, or petroleum to produce electricity. These energy sources are called fossil fuels because they were formed from the remains of ancient sea plants and animals. Most of our electricity comes from fossil fuel plants in the form of coal and natural gas.

Power plants burn the fossil fuels and use the heat to boil water into steam. The steam is channeled through a pipe at high pressure to spin a turbine generator to make electricity. Fossil fuel power plants can produce emissions that pollute the air and contribute to global climate change. The amount and type of emissions can vary based upon the type of fossil fuel and technologies used within the plant.

Fossil fuel plants are sometimes called thermal power plants because they use heat energy to make electricity. (*Therme* is the Greek word for heat.) Coal is used by many power plants because it is inexpensive and abundant in the United States.

There are many other uses for petroleum and natural gas, but the main use of coal is to produce electricity. Over 90 percent of the coal mined in the United States is sent to power plants to make electricity.

Nuclear Power Plants

Nuclear power plants are called thermal power plants, too. They produce electricity in much the same way as fossil fuel plants, except that the fuel they use is uranium, which isn't burned. Uranium is a mineral found in rocks underground. Uranium atoms are split to make smaller atoms in a process called fission that produces enormous amounts of thermal energy. The thermal energy is used to turn water into steam, which drives a turbine generator.

Nuclear power plants do not produce carbon dioxide emissions, but their waste is radioactive. Nuclear waste must be stored carefully to prevent contamination of people and the environment.

Hydropower Plants

Hydropower plants use the energy in moving water to generate electricity. Fast-moving water is used to spin the blades of a turbine generator. Hydropower is called a renewable energy source because it is renewed by rainfall.

Cost of Electricity

How much does it cost to make electricity? Cost depends on several factors.

▪ Fuel Cost

The major cost of generating electricity is the cost of the fuel. Many energy sources can be used. There are also other factors that tie into the cost of a fuel, including production cost, manufacturing or refining costs, cost of transporting the fuel, and more. Hydropower is the cheapest energy source while solar cells are typically the most expensive way to generate power.

▪ Building Cost

Another factor is the cost of building the power plant itself. A plant may be very expensive to build, but the low cost of the fuel can make the electricity economical to produce. Nuclear power plants, for example, are very expensive to build, but their fuel—uranium—is inexpensive. Coal-fired plants, on the other hand, are cheaper to build, but the fuel (coal) is more expensive than uranium.

▪ Efficiency

When figuring cost, you must also consider a plant's efficiency. Efficiency is the amount of useful energy you get out of a system. A totally efficient machine would change all the energy put in it into useful work. Changing one form of energy into another always involves a loss of usable energy. Efficiency of a power plant does not take into account the energy lost in production or transportation, only the energy lost in the generation of electricity.

Combined Cycle vs. Simple Cycle

In the most simple of thermal power plants, a fuel is burned, and water is heated to form high-pressure steam. That steam is used to turn a single turbine. Thermal power plants running in this manner are about 35 percent efficient, meaning 35 percent of the energy in the fuel is actually transformed into useable electrical energy. The other 65 percent is "lost" to the surrounding environment as thermal energy.

Combined cycle power plants add a second turbine in the cycle, increasing the efficiency of the power plant to as much as 60 percent. By doing this, some of the energy that was being wasted to the environment is now being used to generate useful electricity.

In general, today's power plants use three units of fuel to produce one unit of electricity. Most of the lost energy is waste heat. You can see this waste heat in the great clouds of steam pouring out of giant cooling towers on some power plants. For example, a typical coal plant burns about 4,500 tons of coal each day. The chemical energy in about two-thirds of the coal (3,000 tons) is lost as it is converted first to thermal energy, and then to motion energy, and finally into electrical energy. This degree of efficiency is mirrored in most types of power plants. Thermal power plants typically have between a 30-40% efficiency rating. Wind is usually around the same range, with solar often falling below the 30% mark. The most efficient plant is a hydropower plant, which can operate with an efficiency of up to 95%.

Meeting Demand

We don't use electricity at the same rate at all times during the day. There is a certain amount of power that we need all the time called baseload power. It is the minimum amount of electricity that is needed 24 hours a day, 7 days a week, and is provided by a power company.

However, during the day at different times, and depending on the weather, the amount of power that we use increases by different amounts. We use more power during the week than on the weekends because it is needed for offices and schools. We use more electricity during the summer than the winter because we need to keep our buildings cool. An increase in demand during specific times of the day or year is called peak demand. This peak demand represents the additional power above baseload power that a power company must be able to produce when needed.

Power plants can be used to meet baseload power or peak demand, or both. Some power plants require a lot of time to be brought online – operating and producing power at full capacity. Others can be brought online and shut down fairly quickly.

Coal and nuclear power plants are slow, requiring 24 hours or more to reach full generating capacity, so they are used for baseload power generation. Natural gas is increasing in use for baseload generation because it is widely available, low in cost, and a clean-burning fuel.

Wind, hydropower, and solar can all be used to meet baseload capacity when the energy source is available. Wind is often best at night and drops down in its production just as the sun is rising. Solar power is not available at night, and is greatly diminished on cloudy days. Hydropower can produce electricity as long as there is enough water flow, which can be decreased in times of drought.

To meet peak demand, energy sources other than coal and uranium must be used. Natural gas is a good nonrenewable source to meet peak demand because it requires only 30 minutes to go from total shutdown to full capacity. Many hydropower stations have additional capacity using pumped storage. Some electricity is used to pump water into a storage tank or reservoir, where it can be released at a later time to generate additional electricity as needed. Pumped storage hydropower can be brought fully online in as little as five minutes.

Some power plants, because of regulations or agreements with utilities, suppliers, etc., do not run at full capacity or year-round. These power plants may produce as little as 50 percent of maximum generating capacity, but can increase their output if demand rises, supply from another source is suddenly reduced, or an emergency occurs.

Making Decisions

Someone needs to decide when, which, and how many additional generating locations need to be brought online when demand for electricity increases. This is the job of the Regional Transmission Organization (RTO) or Independent System Organization (ISO). ISOs and RTOs work together with generation facilities and transmission systems across many locations, matching generation to the load immediately so that supply and demand for electricity are balanced. The grid operators predict load and schedule generation to make sure that enough generation and back-up power are available in case demand rises or a power plant or power line is lost.

Transmission Organizations

Besides making decisions about generation, RTOs and ISOs also manage markets for wholesale electricity. Participants can buy and sell electricity from a day early to immediately as needed. These markets give electricity suppliers more options for meeting consumer needs for power at the lowest possible cost.

Ten RTOs operate bulk electric power systems across much of North America. More than half of the electricity produced is managed by RTOs, with the rest under the jurisdiction of individual utilities or utility holding companies.

In the 1990s, the Federal Energy Regulatory Commission introduced a policy designed to increase competitive generation by requiring open access to transmission. Northeastern RTOs developed out of coordinated utility operations already in place. RTOs in other locations grew to meet new policies providing for open transmission access.

Members of RTOs include the following:

- Independent power generators
- Transmission companies
- Load-serving entities
- Integrated utilities that combine generation, transmission, and distribution functions
- Other entities such as power marketers and energy traders

RTOs monitor power supply, demand, and other factors such as weather and historical data. This information is input into complex software that optimizes for the best combination of generation and load. They then post large amounts of price data for thousands of locations on the system at time intervals as short as five minutes.

The Continental U.S. Electric Grid



Data: Energy Information Administration

Baseload Balance Assessment

🔗 Questions

1. When considering cost for generating electricity, list other factors that need to be included.

Production (mining and land) costs, manufacturing and refining, cost of transportation to refinery and power plant

2. Compare peak and baseload demand. List several conditions that would change demand.

Baseload demand is the minimum amount of power that a community needs all the time. Peak demand is an increase in demand based on specific times of the day or year. More power is required during the week than on weekends due to offices and schools closing. Cooling or heating oil demands in the summer require more electricity than in the winter. NOTE: Often heating in the winter months is provided by natural gas as an energy source.

3. Which energy sources are most frequently used to produce baseload power and why?

Coal and nuclear power require 24 hours to reach full generation capacity so they are used for baseload generation.

4. When would be the BEST time to use each of the renewables for peak demand?

Wind: Wind is best at night.

Solar: Solar is best during daytime.

Baseload Balance

GENERATION PARAMETERS

Fuel	Capacity	Type of Generation	Time Required for Full Capacity	Cost per Megawatt-hour
Coal	40 MW	Baseload	24 hours	\$40
Nuclear (Uranium)	50 MW	Baseload	24 hours +	\$30
Natural Gas Combined Cycle (NGCC)	20 MW	Baseload	30 minutes +	\$50
Wind	5 MW	Baseload	Immediate when wind speed is sufficient; primarily at night	\$80
Solar	5 MW	Baseload	Immediate when solar intensity is sufficient; only during day	\$180
Hydropower	5 MW	Baseload	5 minutes	\$30
Hydropower Pumped Storage	10 MW	Peak load	5 minutes	\$60
Hydropower	5 MW	Peak load	5 minutes	\$50
Natural Gas Simple Cycle (NGSC)	5-10 MW each site	Peak load	5 minutes	\$90-\$600

Demand

Generation

Peak Demand and Generation Cards

Morning Peak Demand 20 MW	Natural Gas Peak Generation 10 MW \$150 any time
All Day Peak Demand 15 MW	Wind Generation 10 MW \$45 evening only
Evening Peak Demand 15 MW	Solar Generation 10 MW \$75 daytime only
Natural Gas Peak Generation 10 MW \$90 any time	Hydropower Peak Generation 5 MW \$50 any time
Natural Gas Peak Generation 5 MW \$90 any time	Hydropower Peak Generation 10 MW \$60 any time