

Imagine that you could not heat your home in the winter, cook food on a stove, or make a phone call in an emergency. Imagine not being able to use a computer, play video games, watch television, or keep food fresh in a refrigerator. We are very dependent on electricity.

What Is Electricity?



Figure 1 This hydroelectric power plant is transforming the kinetic energy of the falling water into electrical energy.

Electricity is something we generally take for granted. It is something we cannot see, hear, or touch. Electricity is also difficult to describe. In physics, the word “electricity” refers to electrical energy and the movement of charge. When we say, “the electricity went out” or “electricity is expensive,” what we are really saying is, “electrical energy has stopped being transferred” or “generating electrical energy is expensive.”

As you learned in Chapter 5, the law of conservation of energy states that no energy is lost when energy is transformed. This applies to the generation of electricity at power plants, where different types of energy are transformed into electrical energy. For example, in a hydroelectric power plant, kinetic energy from falling water is transformed into electrical energy (**Figure 1**). In a natural gas or nuclear power plant, thermal energy is transformed into electrical energy.

How does the electrical energy get from the power plant to where it is needed? Electricity is transferred through conducting wires in transmission lines. Then electrical devices in your home, at school, and at work transform the electrical energy into another form of energy to perform a task. For example, electrical energy is converted into kinetic energy in an electric fan, sound energy in a speaker system, and into thermal energy in an electric heater.

Electrical Power

Recall from Chapter 5 that power (P) is the rate at which energy is transformed. **Electrical power** is the rate at which electrical energy is produced or consumed in a given time. In this chapter, we will use the terms “power” and “electrical power” interchangeably.

The equation that describes power is $P = \frac{\Delta E}{\Delta t}$. Power is expressed in watts (W), and electrical devices have power ratings that vary widely. In the following Tutorial, you will use the power equation to determine how much power is used by an electrical device.

electrical power (P) the rate of transformation of electrical energy

Tutorial 1 Using the Power Equation

In the following Sample Problem, we will use the equation $P = \frac{\Delta E}{\Delta t}$ to determine how much power is used to charge a cellphone.

Sample Problem 1

Calculate the power required to charge a cellphone if 740 J of energy is transferred in 1.0 min.

Given: $\Delta E = 740 \text{ J}$; $\Delta t = 1.0 \text{ min}$

Required: P

Analysis: $P = \frac{\Delta E}{\Delta t}$

Solution: First convert time to seconds to get the answer in joules per second (J/s), or watts (W):

$$\Delta t = 1.0 \text{ min} \times \frac{60 \text{ s}}{1 \text{ min}}$$

$$\Delta t = 60 \text{ s}$$



$$P = \frac{\Delta E}{\Delta t}$$

$$= \frac{740 \text{ J}}{60 \text{ s}}$$

$$P = 12 \text{ W}$$

Statement: The power required to charge the cellphone is 12 W.

Practice

1. What is the power rating of a digital camera that transforms 120 J in 25 s? 
[ans: 4.8 W]
2. How much power does a hair dryer require to transform 198 000 J of energy in 15 min?  [ans: 220 W]

As you can see from **Table 1**, some devices need very little power, while others need significant amounts of power. Consider all the devices in all the homes in Ontario—a lot of electrical power is needed every day. Employees at the power plant monitor power needs and generate power “on demand.” For example, on a hot summer day, more power is needed for air conditioning. When more power is needed, the power plant employees increase power generation up to the maximum capability. If no more can be generated, then the electricity has to be purchased from somewhere else, such as the United States. As a last resort, the power plant employees may shut down the power to a neighbourhood for a short time. Short temporary interruptions to the electricity supply are called “brownouts.” Brownouts can cause harm to electrical devices because of the rapid change in electrical power. Power is generated on demand because there is no practical method of storing the electrical energy. Batteries are impractical because of the large number that would be needed.

Table 1 Power Ratings

Electrical device	Power rating (W)
MP3 player	0.4
charger for an MP3 player	120
laptop computer	20–75
52 in. LCD TV	220
50 in. plasma TV	380
central air conditioner	7000
stove	6000–10 000

Measuring Electrical Energy

Electrical energy is measured in units of **kilowatt hours** (kWh) because the joule (J) is sometimes too small to be a convenient measurement. One kilowatt hour is equal to 3.6 million joules. A typical home in Ontario uses 1000 kWh of electrical energy each month.

The kilowatt hour is a useful unit of measurement for homes, but when describing the electrical energy generated by a power plant we use megawatt hours (MWh). In 2007, Ontario generated over 158 million megawatt hours of electrical energy. That is approximately 12 100 kWh per person for the year. In general, Canadians use a lot more electrical energy than people in some other parts of the world. By comparison, residents of Chad (a country in Africa), use 9 kWh per person per year. In the following Tutorial, you will determine how much energy a light bulb transforms over a given time period in units of kilowatt hours.

kilowatt hour (kWh) measure of electrical energy

Tutorial 2 Calculating Energy

In the following Sample Problem, we will rearrange the equation $P = \frac{\Delta E}{\Delta t}$ to determine how much energy is transferred in a halogen light bulb.

Sample Problem 1

Calculate the energy needed by a 35 W halogen light bulb that operates for 240 h. Give your answer in both joules and kilowatt hours.

Given: $P = 35 \text{ W}$; $\Delta t = 240 \text{ h}$

Required: ΔE

Analysis: $P = \frac{\Delta E}{\Delta t}$

$$\Delta E = P\Delta t$$

Solution: Convert time to seconds to get the answer in joules:

$$\begin{aligned}\Delta t &= 240 \text{ h} \times \frac{3600 \text{ s}}{1 \text{ h}} \\ &= 864\,000 \text{ s}\end{aligned}$$

$$\begin{aligned}\Delta E &= (35 \text{ W})(864\,000 \text{ s}) \\ &= 3.024 \times 10^7 \text{ J} \quad (\text{two extra digits carried})\end{aligned}$$

To find the answer in kilowatt hours, convert from joules:

$$3.024 \times 10^7 \text{ J} \times \frac{1 \text{ kWh}}{3.6 \times 10^6 \text{ J}} = 8.4 \text{ kWh}$$

Another way of solving the problem is to convert the power from 35 W to kilowatts and then use the power equation:

$$35 \text{ W} \times \frac{1 \text{ kW}}{1000 \text{ W}} = 0.035 \text{ kW}$$

$$\Delta E = P\Delta t$$

$$= (0.035 \text{ kW})(240 \text{ h})$$

$$\Delta E = 8.4 \text{ kWh}$$


Statement: The halogen light needs $3.0 \times 10^7 \text{ J}$ or 8.4 kWh of energy to operate for 240 h.

Practice

1. A compact fluorescent light bulb operates with 7.0 W of power. Calculate the energy it needs to provide light for 24 h. Answer in joules. [T/I](#) [ans: $6.0 \times 10^5 \text{ J}$]
2. Convert your answer in Question 1 to kilowatt hours. [T/I](#) [ans: 0.17 kWh]

Energy Efficiency and Power Plants

Non-renewable sources of energy are running out, and our current renewable sources are not sufficient to meet the demand. To meet the demand for electrical energy, we can use two approaches: conservation and generating energy more efficiently. To conserve energy, newer devices are designed to use less electrical energy than older ones, and people are developing a more critical attitude to the use of electrical energy. At the same time, we have to find ways to improve the efficiency of power plants.

Recall from Chapter 5 that efficiency is a measure of how well a technology transforms energy. Power plants must transform the source energy into electrical energy, a process that is not 100 % efficient (**Table 2**). Engineers can design ways of preventing energy losses during energy transformation. For example, an engineer can improve the efficiency of a coal-fired plant by directing the steam into pipes and increasing its pressure, allowing it to reach much higher temperatures. The higher temperatures make the transfer of energy more efficient. The temperature of the steam in a modern coal-fired plant can reach $600 \text{ }^\circ\text{C}$, and the pressure can be up to 250 times as great as atmospheric pressure. 

CAREER LINK

Power engineers ensure the safe and efficient operation of generators at power plants. To find out more about power engineers,



GO TO NELSON SCIENCE

UNIT TASK BOOKMARK

You can apply what you have learned about electrical energy, efficiency, and power plants to the Unit Task on page 622.

Table 2 Efficiency of Power Plant Technologies

Power plant technology	Average efficiency*	Example of a power plant in Ontario (power-generating capability)	Notes on efficiency
hydro	85 %	Sir Adam Beck II (1499 MW)	Not all of the water is stopped, so some energy is lost.
fossil fuel	45 %	Nanticoke (3640 MW)	Thermal energy is developed from a combustion reaction to produce steam, but not all of the thermal energy is captured.
wind	40 %	Huron Wind Farm (9 MW from 5 turbines)	Not all of the wind is captured, so some energy is lost.
nuclear	35 %	Darlington Nuclear Plant (3500 MW)	Thermal energy is developed from a nuclear reaction to produce steam, but not all of the thermal energy is captured.
solar	15 %	Sarnia Solar Farm (20 MW)	Much of the sunlight is converted into thermal energy instead of electrical energy.

*Efficiency of the power plant technology in general, not the particular technology used in the sample power plant

When considering the pros and cons of sources of energy and power plant technologies, we must consider both environmental aspects and the potential impacts on society. Environmental aspects include the ease of obtaining the source of energy, the dependability of the source of energy, the location of the power plant, atmospheric emissions, and other forms of pollution. Impacts on society include the financial cost of building and operating the power plant, employment opportunities in the plant, safety, and the effects on nearby communities.

Research This

Power Plant Efficiency

Skills: Researching, Communicating

SKILLS
HANDBOOK  A5.1

As you can see from Table 2 on the previous page, the efficiency of power plants varies widely. Having more efficient power plants means using fewer resources and spending less money to operate the power plant. Note that efficiency can describe how well processes work. Operational efficiency describes how much time something is working compared to how much time it is not working. Thermal efficiency describes how much thermal energy is used to perform a task compared to how much thermal energy is wasted.

- Choose one type of electricity generation technology and find some current efficiency numbers. Be sure to focus on thermal efficiency and not operational efficiency.
- Research to find out why some power plants have higher efficiencies than others.
 - State which electricity generation technology you chose and give the thermal efficiency. **T/I**
 - What design feature has most improved the efficiency of this technology? **T/I A**
 - How could implementing that design feature improve other plants using a similar technology? **T/I**
 - Write a one-page report on what could be done to improve the efficiency of other types of power plants. **C A**



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11.1 Summary

- Mechanical energy, thermal energy, and radiant energy are transformed into electrical energy in power plants.
- Electrical power is the rate at which electrical energy is generated or transformed.
- Electrical energy is measured in units of kilowatt hours (kWh) for homes and megawatt hours (MWh) for power plants.
- Power plant technologies vary in efficiency, and each has impacts on the environment and society.
- Improving the efficiency of power plants can decrease our use of resources.

11.1 Questions

- Write a statement that uses the word “electricity” incorrectly (try to think of an example that you have heard). What does the word “electricity” refer to? **K/U C**
- A car battery transfers 19 200 J of energy to the starter in 2.0 s when you turn the key to start the engine. Calculate the power of the starter. **T/I**
- A 1200 W microwave oven transforms 1.8×10^5 J of energy while reheating some food. Calculate how long the food was in the microwave. Answer in minutes. **T/I**
- A plasma television requires 380 W to operate. A family watches television for 110 h in one month. Calculate how much energy is needed. Answer in joules and kilowatt hours. **T/I**
- How much television does the family in Question 4 watch in a year? Calculate how much energy is needed to power the television annually. Answer in joules and kilowatt hours. **T/I**
- Look at Table 2 on page 506 and choose a power plant technology that you found particularly interesting. What was your reaction to reading about its efficiency? Write a few sentences about your reaction. **C A**