Key Terms

electrical power
watt (W)
kilowatt (kW)
electrical energy
kilowatt-hour (kW·h)
EnerGuide label
smart meter
time of use pricing
phantom load
efficiency

12.2 Using Electrical Energy Wisely

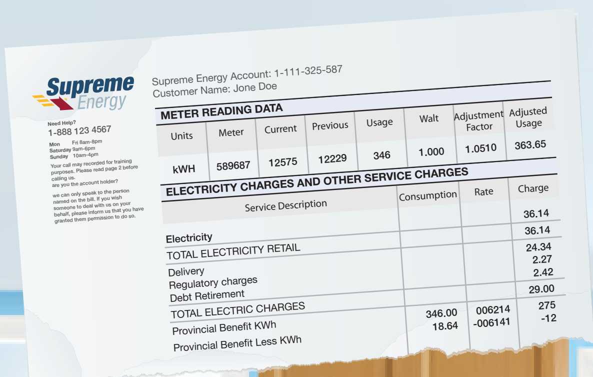
Choosing appliances carefully and choosing when to use them can make a big difference in the financial and environmental cost of electrical energy.

What You Pay For

A typical electrical energy bill is shown in **Figure 12.8.** It includes charges for the energy used, charges related to the cost of distributing the energy, and administration charges. **Figure 12.9** illustrates some of the savings that can be made by the choices of appliances and lighting in your home.

The energy bill in **Figure 12.8** shows the energy that was used as the difference between two readings—346 kW·h. It also shows an adjustment factor of 1.0510. This adjustment factor represents an allowance for the energy "lost" (converted to heat in wires and transformers) during transmission. The adjusted usage is 346 kW·h × 1.0510 = 363.65 kW·h, which is the amount of energy that the customer must pay for.

The amount of electrical energy that is used in your home depends on three factors: the power ratings of the appliances and devices used, the settings on the appliances and devices (such as high, medium, or low), and the amount of time that each appliance or device is used. The *cost* of electricity depends on the amount of energy that is used and the price that is charged for it.



Supreme Energy

Need Help?
1-888 123 4567
Mon Fri 8am-8pm
Saturday 9am-6pm
Sunday 10am-4pm
Your call may recorded for training purposes. Please read page 2 before calling us.
are you the account holder?
we can only speak to the person named on the bill. If you wish someone to deal with us on your behalf, please inform us that you have granted them permission to do so.

Supreme Energy Account: 1-111-325-587
Customer Name: Jone Doe

METER READING DATA

Units	Meter	Current	Previous	Usage	Walt	Adjustment Factor	Adjusted Usage
kWH	589687	12575	12229	346	1.000	1.0510	363.65

ELECTRICITY CHARGES AND OTHER SERVICE CHARGES

Service Description	Consumption	Rate	Charge
Electricity			36.14
TOTAL ELECTRICITY RETAIL			36.14
Delivery			24.34
Regulatory charges			2.27
Debt Retirement			2.42
TOTAL ELECTRIC CHARGES			29.00
Provincial Benefit KWh	346.00	006214	275
Provincial Benefit Less KWh	18.64	-006141	-12

Figure 12.8 This is a typical electrical energy bill for a home in Ontario. It includes many charges that are based on how much energy was used. The difference between the meter readings at the beginning and end of a time period indicates the energy that was used by the customer.

Figure 12.9 The labels on the appliances indicate energy savings of new models compared with standard older models.

Power Ratings

One factor that affects the amount of electrical energy used in your home is the power ratings of your appliances and devices. **Figure 12.10** shows the ratings of some compact fluorescent bulbs. A brighter bulb has a higher rating. **Table 12.2** lists several appliances and their typical power ratings. The actual power rating of any particular appliance appears on a label on the outer casing of the appliance. The value given there is usually the maximum power used. The **electrical power** of an appliance is its rate of use of electrical energy. Electrical power is measured in **watts (W)**, although the practical unit for most appliances is the **kilowatt (kW)**, which is 1000 watts.

electrical power the rate at which an appliance uses electrical energy

watt (W) a unit of electrical power

kilowatt (kW) a practical unit of electrical power; 1 kW = 1000 W

Appliance Settings

A second factor that affects the amount of electrical energy used by appliances and devices is their settings. The actual power used may be different from the power rating, depending on the setting or what the appliance is doing. For example, the wash cycle of a clothes washer requires more power than the spin cycle.

Table 12.2 Typical Power Ratings of Appliances

Appliance	Typical Power Rating (kW)
Clock	0.0050
Clothes dryer	5.0
Clothes washer	0.50
Coffee maker	1.0
Computer with monitor and printer	0.20
Dishwasher	1.8
DVD player	0.040
Freezer	0.34
Light: Incandescent (60 W) Compact Fluorescent (60 W equivalent)	0.060 0.018
Microwave oven	1.5
Electric stove: Self-cleaning Not self-cleaning	3.2 3.5
Refrigerator: Older model Energy Star®	0.40 0.35
Stereo	0.030
Television: Cathode Ray Tube (CRT) Liquid Crystal Display (LCD) Plasma	0.20 0.12 0.28
Toaster	1.1
Toaster oven	1.2
Vacuum cleaner: Portable Central vacuum	0.80 1.6
Video game console	0.10

Figure 12.10 Bulbs with lower power ratings are used for areas that need less light, such as storage rooms.

Go to **scienceontario** to find out more

Amount of Use

A third factor that affects the amount of electrical energy used in your home is how long each appliance or device is used. Obviously, leaving a bulb on for 10 h consumes 10 times as much energy as leaving the same bulb on for 1 h. The **electrical energy** that is used is calculated by multiplying the power rating of an appliance or device (in kW) by the amount of time that the appliance or device is used (in hours, h). Thus, the practical unit of electrical energy is the **kilowatt-hour (kW·h)**. Note that the kW·h combines the units for power × time. The joule, which is the unit for any form of energy, also combines the units for power × time: J = W·s.

electrical energy the energy that is used by an appliance at a given setting; determined by multiplying the power rating of an appliance by the length of time it is used

kilowatt-hour (kW·h) the practical unit of electrical energy

EnerGuide label a label that gives details about how much energy an appliance uses in one year of normal use

EnerGuide Labels

In Canada, any household appliance that is sold must have an **EnerGuide label**. As in **Figure 12.11**, the label shows how much energy an appliance uses in one year of normal use. The Canadian Standards Association tests major appliances to make sure they meet minimum energy efficiency standards.

Consumers should use the EnerGuide label to help them make an informed choice when they purchase a refrigerator, freezer, stove, dishwasher, clothes washer, dryer, or room air conditioner. Products earn an Energy Star® rating when they use 10 to 50 percent less energy (and water, for appliances such as clothes washers and dishwashers), compared with a standard product in the same category. **Table 12.3** shows the typical energy that is used in one year by various appliances.

Table 12.3 Annual Energy Used for Common Household Appliances in Canadian Homes

Appliance	Typical Annual Energy Used (kW•h/year)
Electric clothes dryer	912
Clothes washer:	
Older model	573
Energy Star®	267
Dishwasher:	457
Older model	422
Energy Star®	
Freezer	344
Electric stove:	
Self-cleaning	622
Not self-cleaning	694
Refrigerator:	
Older model	465
Energy Star®	411

Figure 12.11 This front-loading clothes washer uses far less electrical energy in one year of normal use than a top-loading model does. The indicator arrow shows how this appliance compares with other appliances in the same category. The farther left the indicator arrow is, the lower the cost to use the appliance is. This appliance has earned an Energy Star® rating.

Cost of Electrical Energy

The cost of electrical energy depends on the amount of energy that is used and the price that is charged for it. This cost is calculated by multiplying the amount of energy used (in kW·h) by the price (in ¢/kW·h).

Sample Problem: Cost of Using a Hair Dryer

Problem

A hair dryer is rated at 1200 W. On average, it is used for 10 min each school day in the morning, when the cost of electrical energy is 8.8¢/kW·h. What is the cost of using the hair dryer on all five school days during one week?

Solution

Part 1: Power = $1200\text{ W} = \dfrac{1.20\ \cancel{\text{W}}}{1000\ \cancel{\text{W}}/\text{kW}} = 1.20\text{ kW}$

$$\text{Time} = 10\,\frac{\text{min}}{\cancel{\text{day}}} \times 5\ \cancel{\text{days}} = \frac{50\ \cancel{\text{min}}}{60\ \cancel{\text{min}}/\text{h}} = 0.833\text{ h}$$

Energy used = power × time = 1.20 kW × 0.833 h = 1.0 kW·h

Part 2: Rate = 8.8 ¢/kW·h

Cost = energy use × rate

$$= 1.0\ \cancel{\text{kW·h}} \times 8.8\,\frac{¢}{\cancel{\text{kw·h}}} = 8.8\ ¢$$

The hairdryer costs 9¢ to use on all five school days.

Check Your Solution

The final answer has the correct units, and the cost is reasonable.

Sense of Value

In the first stage of generating electrical energy from fossil fuel, the fuel is burned to turn water into steam at a power station. The steam is then used to drive turbines in a generator; transformers step up the voltage as the energy is fed to transmission lines; and the energy is then distributed. By the time the energy reaches consumers, about 70 percent of it has been lost to heat.

GRASP

Go to **Science Skills Toolkit 9** to learn about an alternative problem solving method.

Practice Problems

1. Convert the following power ratings to kW.

a. hot plate 1300 W **b.** ceiling fan 60 W **c.** coffee maker 900 W

2. Convert the following times to hours.

a. 5 min **b.** 20 min **c.** 70 min

3. How much energy is used when a 1.25 kW toaster oven is used for a total of 3 h in a month?

4. The estimated average energy that is used to operate a clothes dryer for a year is 912 kW·h. If the average rate to operate the dryer is 7.15 ¢/kW·h, what is the average cost per year?

5. Calculate the cost of watching television for 3 h at night at a rate of 8.8¢/kW·h. The television has a power rating of 150 W.

Smart Meters

A **smart meter**, shown in **Figure 12.12**, records the total electrical energy used each hour. The data are sent to the utility company automatically. Ontario plans to replace all older meters with smart meters by 2010. Then, all electricity bills for residences will be based on time of use pricing.

smart meter a meter that records the total electrical energy used hour by hour and sends this information to the utility company automatically

time of use pricing a system of pricing in which the cost of each kW·h of energy used is different at different times of the day

Figure 12.12 Smart meters encourage conservation by making us think about how and when we use electrical energy.

Time of Use Pricing

Time of use pricing is a system of pricing in which the price that is charged for each kW·h of energy used is different at different times of the day or week. **Figure 12.13** shows typical time of use intervals and the price charged for energy that is used during each interval. There are three different time of use prices, which correspond to off-peak, mid-peak, or on-peak use. These intervals are adjusted twice each year because the demand for electricity changes with the seasons. In the summer, the demand is greater during the middle of weekdays, when many people are using air conditioners. In the winter, the demand is greater in the morning and evening, when people need light and heat.

The price of electrical energy is lowest on weekends and holidays. Thus, even if the amount of energy used is the same, its total cost varies.

Suggested Investigation

Real World Investigation 12-B, An Electrical Energy Audit, on page 514.

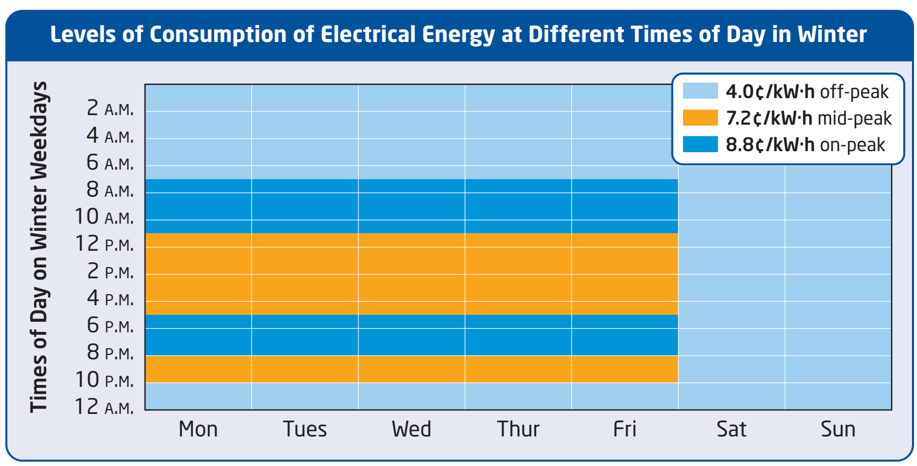


Figure 12.13 Different time of use prices reflect the changing cost of generating electricity throughout the day.

Learning Check

1. What factors determine the amount of electrical energy that is consumed by an appliance?
2. Use the data in **Table 12.2** to determine which appliance uses the most electrical energy: a clothes dryer that operates for 30 min or a freezer that operates for 24 h.
3. Explain how you would use an EnerGuide label to help you choose a new refrigerator.
4. How can you use information about time of use prices to reduce your family's energy bill?

Phantom Loads

Many appliances are in stand-by mode when they are not switched on. For example, if you have a remote control to turn on a television, the television must be able to sense the signal, which requires energy. The electricity that is consumed by an appliance when it is turned off is called the **phantom load**. Clock displays, such as those on microwaves and coffee makers, and external power adapters also require phantom loads. External power adapters plug into wall outlets and change the electricity to low voltage alternating or direct current. If you touch an external power supply, as shown in **Figure 12.14**, you will notice that it is quite warm. It is estimated that an average home has a phantom load of about 50 W.

A meter, such as the one shown in **Figure 12.15**, can be used to measure the power ratings of appliances. The meter plugs into a wall outlet, and an appliance can be plugged into an outlet in the meter. The meter will display the power that is drawn by the appliance when it is on or off. The easiest way to prevent a phantom load is to unplug an appliance.

Electrical Devices, Energy, and Efficiency

An efficient electrical device does what you want it to do, with a minimum conversion of energy to unwanted forms. For example, you do not want heat from a computer or a TV set. The **efficiency** of an electrical device is the ratio of useful energy output to total energy input, expressed as a percentage:

$$\text{Percent efficiency} = \frac{\text{useful energy output}}{\text{total energy input}} \times 100\%$$

The total energy input for an electrical appliance is its power multiplied by the time it is on. The energy that is absorbed when a known amount of water is heated is relatively easy to determine. This method is used to find the energy output of water-heating appliances.

Figure 12.14 External power adapters are sometimes called wall warts. These adapters are inefficient and give off a substantial amount of heat.

Figure 12.15 You can measure the power that an appliance uses by connecting it to a watt-meter. You can also use the meter to measure the phantom load (if there is one) when an appliance is turned off.

phantom load the electricity that is consumed by an appliance or device when it is turned off

efficiency the ratio of useful energy output to total energy input, expressed as a percentage

Sense of scale

When your body is at rest (in a classroom, for example), it is generating heat that is roughly equivalent to the energy output of one 60 W incandescent bulb (or four 15 W compact fluorescents). Thus, you and 16 of your classmates generate about 1 kW of heat.

Suggested Investigation

Data Analysis Investigation 12-C, A "Dry" Investigation, on page 515

Study Toolkit

Using Graphic Organizers
How can using a Venn diagram help you compare and contrast an incandescent bulb and a compact fluorescent bulb?

GRASP
Go to **Science Skills Toolkit 9** to learn about an alternative problem solving method.

The Unit of Electrical Energy

The SI unit of energy is the joule (J). One joule is equivalent to a power of one watt operating for one second (W·s). Thus, 1 J = 1 W·s. This is a small amount of energy, so a unit of one thousand joules, the kilojoule, is more convenient to use. Thus, 1 kJ = 1 kW·s. The energy input to an electrical device is usually stated as its power (in kW) multiplied by the time (in s) that it operates.

Sample Problem: Electric Kettle or Microwave?

Problem

To compare the efficiency of a microwave with the efficiency of an electric kettle, Sara placed 500 mL of water into each. Sara's teacher helped her calculate the energy required to boil the water, which was 168 kJ. The kettle, which had a power rating of 1.5 kW, took 132 s to boil the water. The microwave had a power rating of 1.2 kW and took 280 s to boil the water. Which is more efficient?

Solution

You need to calculate the efficiency of the microwave and the electric kettle.
The useful energy is 168 kJ.

Kettle: Energy input = 1.5 kW × 132 s = 198 kW·s = 198 kJ

$$\text{Percent efficiency} = \frac{168\ \cancel{\text{kJ}}}{198\ \cancel{\text{kJ}}} \times 100\% = 85\%$$

Microwave: Energy input = 1.2 kW × 280 s = 336 kJ

$$\text{Percent efficiency} = \frac{168\ \cancel{\text{kJ}}}{336\ \cancel{\text{kJ}}} \times 100\% = 50\%$$

The kettle is more efficient than the microwave for heating water.

Check Your Solution

The solution is reasonable. The microwave took about twice as long to boil the water, while its power rating is not much less.

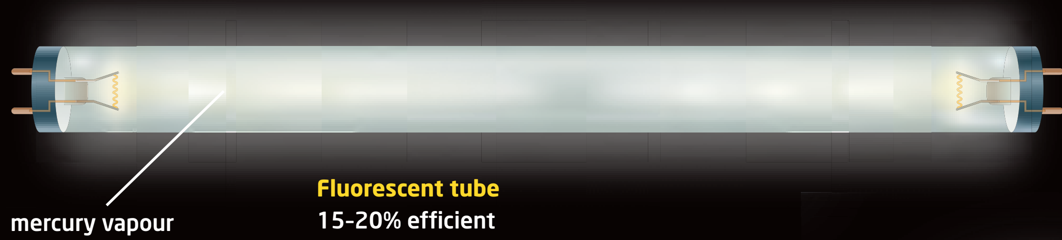
Practice Problems

1. The spin cycle of a clothes washer operates for 3 min at a power of 300 W. The useful output from the washer is 40 kJ. What is the efficiency of the washer?
2. An AC power adapter operates at 28.6 W. The output from the adapter is 1.04 W. What is its efficiency?
3. Two nuclear reactors provide 3200 MW of power. If the transmission system loses 5.1% of the energy produced, how much power from these two reactors would customers receive?
4. A motor is 80 percent efficient. How much useful work can the motor do if it is supplied with 200 kW·h of energy?

The Efficiency of Light Sources

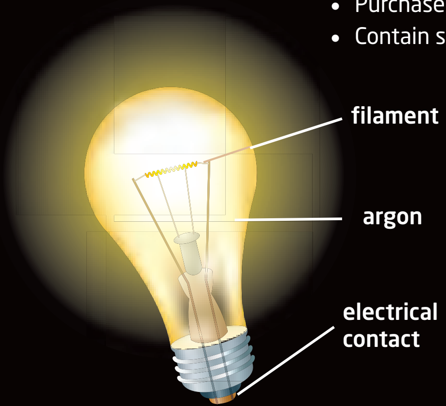
In Ontario alone, the electricity wasted by the use of incandescent bulbs is enough to power 600 000 homes. As you can see in **Figure 12.16**, incandescent light bulbs are hugely inefficient. Fortunately, there are other ways to convert electricity into light.

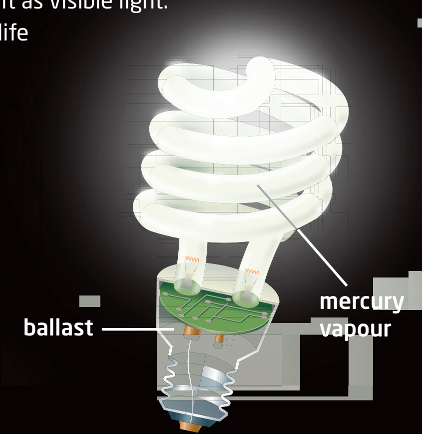
Figure 12.16 Different light sources have a variety of advantages and disadvantages.



Fluorescent tube
15–20% efficient
Voltage excites mercury atoms that emit invisible light. A coating on the inside of the tube absorbs light and re-emits it as visible light.

- Purchase price high; low operating costs; long life
- Contain small amounts of mercury



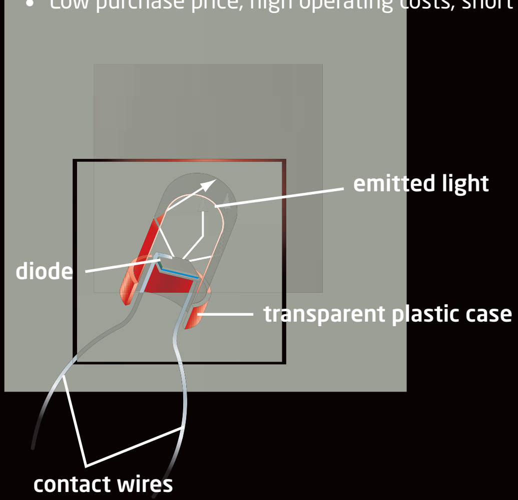


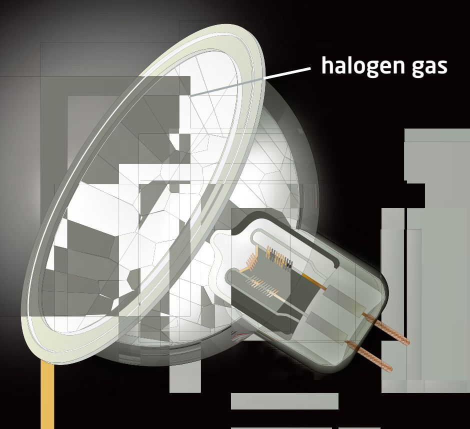
Incandescent light bulb
5–8% efficient
A long, thin tungsten filament is heated to about 2200°C. The filament gradually evaporates, but the process is slowed by argon or other inert gas.

- Low purchase price; high operating costs; short lifetime

Compact fluorescent light bulb (CFL)
15–20% efficient
Fluorescent bulbs are coiled to fit into the space of an incandescent bulb.

- Purchase price high; low operating costs; long life
- Contains small amounts of mercury





Light-emitting diode (LED)
25–50% efficient
A semiconductor chip (diode) emits light that is focused by a plastic case.

- Purchase price high; very low operating costs; very long life

Halogen lamp
20% efficient
A tungsten filament, whose evaporation is slowed by a gas, often iodine, is heated to more than 2500°C.

- Lasts longer than incandescent bulb

Section 12.2 Review

Section Summary

- The electrical power of an appliance is the rate at which it uses electrical energy. The practical unit for electrical power is the kilowatt (kW).
- The electrical energy that is used by an appliance at a given setting is calculated by multiplying its power rating (in kW) by the amount of time that it is used (in hours, h). The practical unit of electrical energy is the kilowatt-hour (kW·h).
- The cost of electrical energy is calculated by multiplying the amount of energy that is used (in kW·h) by the price (in ¢/kW·h).
- Smart meters allow a utility company to charge a different amount for each kW·h of energy that is used at different times of the day.
- The electricity that is consumed by any appliance or device when it is turned off is called the phantom load.
- The efficiency of an electrical device is the ratio of useful energy output to total energy input:

$$\text{Efficiency} = \frac{\text{useful energy output}}{\text{total energy input}}$$

Review Questions

K/U **1.** What is the difference between electrical power and electrical energy?

K/U **2.** What are the three factors that determine the total amount of electrical energy consumed in a home?

T/I **3.** Look at **Figure 12.13** on page 496. Why is there a high demand for electricity between 5:00 P.M. and 8:00 P.M. in the winter?

T/I **4.** If you go away on a vacation, why might your family still be billed for electrical energy used in your home?

K/U **5.** A water pump operates for 1 h, and its output is 1700 kJ of useful energy. Calculate the efficiency of the water pump, if it has a power rating of 1200 W.

T/I **6.** Refer to the table on the right. How much energy is consumed in 12 h by an electric toothbrush that is plugged in but is not in use?

Typical Phantom Loads of Some Common Appliances

Appliance	Typical Phantom Load (W)
Cable television	12.5
Computer and printer	7.0
Electric toothbrush	1.6
Microwave	3.0
Cordless telephone	2.5

K/U **7.** Some sources claim that lighting accounts for up to 15 percent of home electricity costs. Explain how you would collect and analyze data to test this claim.

T/I **8.** A 60 W incandescent bulb costs $1.25 and has an average lifetime of 1500 h. A 15 W compact fluorescent bulb, which gives the same amount of light, costs $4.00 and has an average lifetime of 10 000 h. Compare the lifetime cost of buying and operating the incandescent bulb with the lifetime cost of buying and operating the compact fluorescent bulb. Assume that the average cost of electrical energy is 8.0 ¢/kW·h.

C **9.** Based on your answer to question 8, make an argument for which bulb is the more economical choice.