ENERGY

What is the Cost of Inefficiency?

Key Concept

Students learn about work, energy and power and that using electrical appliances and devices has economic and environmental costs.

Time Required

150 minutes

Grades

6-8, 9-12

Next Generation Science Standards

Disciplinary Core Ideas

- MS-PS3.A | HS-PS3.A
  Definitions of Energy
- MS-PS3.B | HS-PS3.B
  Conservation of Energy and Energy Transfer
- MS-ETS1.A | HS-ETS1.A
  Defining and Delimiting Engineering Problems
- MS-ETS1.B | HS-ETS1.B
  Developing Possible Solutions
- MS-ETS1.C | HS-ETS1.B
  Optimizing the Design Solution
- HS-PS2.A
  Forces and Motion
- HS-PS2.B
  Types of Interactions

Cross Cutting Concepts

- Cause and Effect
- Energy and Matter

Science and Engineering Practices

- Planning and Carrying out Investigations
- Analyzing and Interpreting Data
- Asking Questions and Defining Problems

BACKGROUND

The U.S. Department of Energy projects that the demand for electricity will increase nearly 50% by 2050. Improving the efficiency of homes, businesses, schools, governments, and industries is one of the most constructive, cost-effective ways to address the challenges of high energy prices, energy security and independence, environmental concerns, and global climate change in the near term. Mining this efficiency could help us meet up to 50% of the expected growth in U.S. consumption of electricity in the coming decades. This would yield billions of dollars in saved energy bills and avoid significant emissions of greenhouse gases and other air pollutants.

Energy efficiency and energy conservation are necessary first steps toward a sustainable energy future. All energy users need to understand the value of energy efficiency.

OBJECTIVES

At the end of the lesson, students will:

- define the concepts of work, power, and energy, and provide examples of each
- describe the relationship between work, power, and energy
- know how to calculate the economic and CO2 savings from using energy-efficient appliances
- understand the concepts of energy efficiency and energy conservation and provide examples of each

ADDITIONAL RESOURCES

Additional resources, including slides and videos, for this lesson can be found at kidwind.org/ww/costinefficiency.

MATERIALS

For each station:

- 2 lamps
- 2 light bulbs of equal brightness (measured in lumens); incandescent and compact florescent are included in the activity kit. For additional comparison you can also look for new LED bulbs
- Kill A Watt Meters

For each student:

- Calculator
- The Economic and Environmental Cost of Using Appliances Activity Sheet
- Reading Passage: Energy Efficiency
- Energy Efficiency Activity Worksheet

Click here to check out the NGSS Website, Full NGSS Standards, or Science and Engineering Practices in the NGSS.

GETTING READY

Make copies of all student sheets. Read over the lesson information and become comfortable with the concepts. Practice using the Kill A Watt Meter and doing the calculations in Part 2: Measuring Power and Energy. Set up three stations with a lamp, light bulbs, and Kill A Watt Meter.

PART I: WORK, POWER AND ENERGY (45 MINUTES)

Step 1: Introduction

Ask students some questions to get them thinking about using electricity, such as:

- What electrical appliances and devices do you use at home?
- Which appliances do you think uses the most electricity in your house? Why?
- What electrical appliances and devices do we use in our classroom?
- Which appliances use the most electricity in our classroom? Why?
- Why is it important to conserve electricity?
- Is there a way to measure how much electricity appliances and devices use? If so, what is it?

Step 2: Discuss the concept of work

Tell students that the scientific definition of work is a force causing a displacement (the change in an object's location by any force). Write these definition on the board.

Demonstrate this concept to students by lifting an apple one meter. We are using an apple as it represents a mass of 100 grams. The concept of work can be shown by displacing the apple one meter. This can be done quickly or slowly—the amount of work does not change. Power is equal to work/time, or the rate at which work is done 1 watt of power would be equal to lifting this 100 gram apple, 1 meter in 1 second. A Newton is a unit of force. It is equal to the force that would give a mass of one kilogram an acceleration of one meter per second per second.

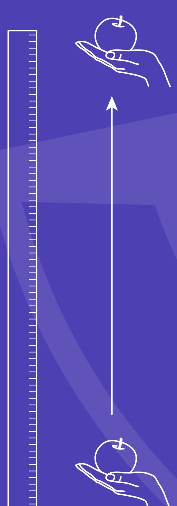
Using the definition of work on the board, ask students to tell you why work was done during this demonstration. Answer: You have applied a force to the apple, and displacing it (moved it up one meter).

Ask students to provide other examples of work that can be observed in everyday life such as a tractor pulling a plow through a field, a father pushing a grocery cart down the aisle of a grocery store, a student lifting a backpack full of books upon her shoulder, a weightlifter lifting a barbell above his head, an Olympian launching the shot-put, etc. In each of these examples, a force is exerted on an object that results in the object being displaced.

The amount of time it takes to do work has nothing to do with the amount of work being done. Whether it took you two seconds or four seconds to lift the apple, the same amount of work was done. Whether it took the father one minute or three minutes to move the shopping cart down the aisle does not change the amount of work that was done.

POWER

$$\text{Power} = \frac{\text{Work}}{\text{Time}}$$



A simple demonstration of work and power can be done using an apple with a mass of 100 grams.

Step 3: Discuss the concept of power

Tell students that the definition of power, on the other hand, is a measure of how quickly a certain amount of work can be done, or the rate at which work is done.

Let's return to the example of lifting the apple. Power depends on the time it takes to raise the apple one meter. Whether the apple is lifted rapidly or slowly, it's the same amount of work. If it is lifted rapidly, the same amount of work is being done in a shorter period of time, and more power needs to be applied.

In order to sell his newly improved steam engines, James Watt was forced to combine the idea of time with the definition of work.

The equation for power is force times distance divided by time:

$$P = \frac{W}{t}$$

But F×D=Work, so power is equal to work divided by time or:

$$P = \frac{F \times D}{t}$$

The basic unit of work in the metric system is the joule and a joule per second is known as a watt (W).

A watt is roughly the amount of power needed to lift 100 grams (the mass of a average sized apple) one vertical meter of height in one second. Demonstrate one watt by lifting the apple one meter in one second (the amount of time it takes to slowly say one-one thousand).

Ask students if you need to be "powerful" to lift one apple one meter in one second. Explain to the students that because a watt is a small unit of measurement, kilowatts (kW) and megawatts (MW) are sometimes used. A kilowatt is 1,000 watts, or the power needed to raise 1,000 apples one meter in one second. A megawatt is a million watts. Do you have to be "powerful" to lift one thousand or one million apples one meter in one second?

Note: Horsepower is occasionally used to describe the power delivered by an engine. One horsepower is equivalent to 746 watts, or lifting 550 pounds, one foot in one second.

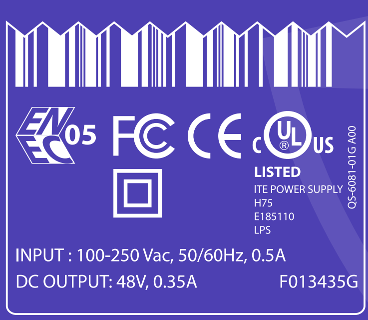
Step 4: Discuss the concept of energy

Tell the students that the amount of energy an appliance or device uses depends on how much power (watts) is needed to operate it and, more importantly, how much time it is consuming that power. A powerful car does not use any energy (gas) if it is parked in the garage all day. The same car consumes a lot of energy during an eight-hour drive to Grandma's house, however. The equation for energy is power x time:

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

Energy is the capacity for doing work. It is a quantity, not a rate. Since the joule is a very small quantity of work or energy, explain that electrical energy is measured in larger units known as the watt-hour (3600 J), kilowatt-hour (1000 Wh), or a megawatt-hour (1,000,000 Wh). To determine how much energy an appliance uses in joules, you have to multiply the number of watts needed to operate it by the length of time that it is "on" in seconds. Watts × seconds = wattseconds (Ws), also known as a joules (J).

EXAMPLE POWER LABEL



PART 2: MEASURING POWER AND ENERGY (45 MINUTES)

Step 1: Demonstrate how to use a Kill A Watt Meter

Distribute the Kill A Watt Meter Student Sheet and the Economic and Environmental Cost of Using Appliances Activity Sheet. Show students the Kill A Watt Meter and explain that it is an instrument that measures the power it takes to run a device and the amount of energy the device consumes.

Demonstrate how to use a Kill A Watt Meter with a device in your classroom or an appliance from home, i.e. a laptop charger, table lamp, or a pencil sharpener. Go over the directions with the class, plug in your example appliance or device, and demonstrate how the meter can record both power (kilowatts) and energy (kilowatt-hours). See data collection sheet.

Step 2: Determine the power the appliance uses

The power is measured by pushing the Watt/VA (Power/Apparent Power) key. With the meter plugged into a wall socket or extension cord and the appliance plugged into the meter, press the Watt/VA key.

Note: The Watt/VA Key is a toggle function key. Press the Watt/VA key once to display watts. Press the key again to display the VA meter. Tell students to record the power of the appliance/device you are demonstrating using the Watt function. The power drawn by the average LCD television, for example, is 120 W.

Appliances draw different amounts of power, depending on their use. Make sure students use the appliance to see how it affects power consumption. For example, turn the fan on low, medium, and high. Let the computer go into sleep mode. Students may have to choose an average number for this column.

Step 3: Estimate the amount of time the appliance is on in one day

Determine about how long the appliance is using power during the day. If you round this number off to the nearest hour, the next calculation will be easier, but using 15 minute segments will provide more accuracy.

In the LCD television example, the estimated time is 4 hours.

Step 4: Determine the amount of electrical energy the appliance uses in one day

Energy is measured by pushing the KWH/Hour toggle function key. Press the KWH/Hour key once to show the cumulative energy consumption since power was applied to the unit. Then press the key to display the cumulative time since power was applied to the unit.

Energy consumption will be displayed in kilowatt-hours (from 0.01 KWH to 9999 KWH). Time will initially be displayed as hours:minutes (from 00:00) and then will switch to hours (to 9999). To reset, remove the power from the unit momentarily.

It is very challenging to collect enough energy data in one class period to get measurable data that is accurate. If you have time, you can set up a Kill A Watt Meter early in the morning and leave it on during the day to see how much energy the appliance you are testing has consumed.

USING KILL A WATT METERS

Kill A Watt Meters are great tools to see power and energy being used by appliances. In a classroom it can be challenging to measure energy due to short lab times. To get around this set up a few meters to measure energy use at the beginning of the day or week.

Another cool thing you can do is let students sign them out for a week and collect data at home. As a class you can aggregate this data for analysis.

During class it is a good idea to have many appliances that students can plug into the Kill A Watt so students can experiment.

We recommend collecting power consumption data with the Kill A Watt and then estimating how much energy your device would consume in a day.

Energy Consumed (Day) = Watts × Hours Device is Used

480 Watt-hours (Wh) = 120 Watts × 4 hours

To make things simple for later calculations, convert watt-hours (Wh) to kilowatt hours (kWh).

$$\text{kWh} = \frac{\text{Wh}}{1000}$$

$$.48\text{kWh} = \frac{480\text{Wh}}{1000}$$

Step 5: Calculate how many kilowatt-hours the appliance uses in one year

To calculate the amount of energy an appliance or device consumes in one year, multiply the amount it uses in one day times 365. Tell students to do this calculation for the demonstration appliance or device and record the amount on their worksheet.

In the television example, 0.48 kWh per day times 365 days equals 175.2 kWh. The television consumes 175.2 kilowatt-hours in one year.

Step 6: Calculate the yearly cost of running the appliance

Once you have determined the number of kilowatt-hours the appliance uses in one year, you multiply this number by the amount your power company charges you for each kWh of electricity. In April 2023, the national average cost of electricity was $0.16 per killowatt-hour.[2] Use the map on page 9 to explore energy costs and sources in your state.

The television consumes 175.2 kWh per year; 175.2 times $0.16 equals $28.03. It costs $28.03 to watch four hours of television each day for one year.

Step 7: Determine the amount of carbon dioxide (CO2) generated in one year by the appliance

Different sources of energy are used to produce electricity. Each source produces a different amount of CO2 emissions. Coal produces more CO2 than any other method of generating electricity. Up until the late 2010s, coal was the primary source of electricity production in the United States. The national average for all methods of generating electricity is 0.39 kg CO2e (e signifies the carbon dioxide that contributes to warming). To calculate the yearly amount of carbon dioxide produced by running an appliance, you multiply the number of kWh of electricity it consumes in one year by 0.39. Ask students to do this calculation and record the result in the seventh column of the second row. Students can use the map on page 9 to determine the amount of CO2 that each kWh produces in their state.

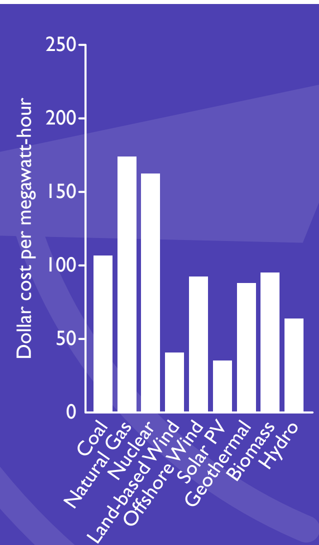
The television consumes 175.2 kWh per year: 175.2 times 0.39 kg CO2e (e signifies the carbon dioxide that contributes to warming) equals 68.33 kilograms of carbon dioxide.

PART 3: ENVIRONMENTAL IMPACT (45 MINUTES)

Step 1: Calculating the cost and environmental impact of light bulbs

Divide students up into three groups and ask each group to record the type of light bulb they are measuring (incandescent, compact florescent, or LED if you used these bulbs) in the first column of the third row. Tell them to complete the calculations for their bulb. If students are

AVERAGE (UNSUBSIDIZED) LCOE FROM 2021 LAZARD STUDY ON COST OF ELECTRICITY PER SOURCE PER MWH.[1]



Lazard. (2021). Lazard's Levelized Cost of Energy Analysis—Version 15. Lazard.

not confident about doing this on their own, you can do this as a classroom demo.

Step 2: Discussion of their findings

Discuss what the students discovered. Discuss the economic and environmental costs of each bulb.

- Which type of light bulb consumed the most power? The least power?
- Which type of light bulb used the most energy in a year? The least energy?
- Which type of light bulb costs the most to operate for a year? The least?
- Which type of light bulb produced the most carbon dioxide in a year? The least carbon dioxide in a year?
- Were there any surprises?

Compare your calculations to the data on the box of light bulbs. This is a very good consumer math activity.

PART 4: ENERGY EFFICIENCY (15 MINUTES)

Step 3: Introduction

- What do you think energy efficiency means? What are some examples?
- What do you think energy conservation means? What are some examples?

Step 4: Energy efficiency reading passage

Ask students to read the passage.

Step 5: Discussion

Ask students which type of light bulb is the most efficient. Ask them to explain their answer.

Remind students that all energy transformations result in waste heat; the amount of "lost" heat is not the same in each transformation (this concept was covered in Lesson 1). Energy efficiency is a measure of how well a device transforms or converts one form of energy to another. The less energy that is "lost," the more efficient the transformation and the more efficient the device. In the case of light bulbs, the energy transformation we're looking for is electrical energy into radiant energy (light). The incandescent bulb transforms only 10% of the electrical energy into radiant energy. Consequently, we say that it is only 10% efficient because 90% of the electrical energy is transformed into thermal energy (waste heat). An incandescent light bulb is not a very efficient device.

On the other hand, 65% of the electrical energy powering a compact florescent light bulb is transformed into radiant energy, so we say that it is 65% efficient because 35% is lost to thermal energy (waste heat). This is why many people are switching from incandescent bulbs to compact fluorescents. Compact fluorescents not only save energy; they also save us money because we need to pay a power company for the electricity we use.

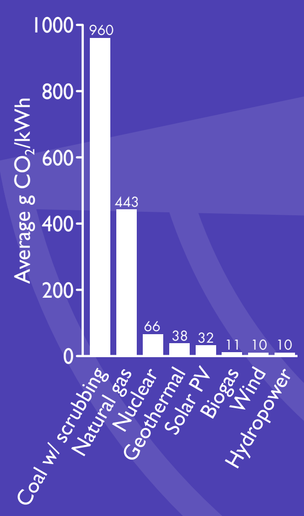
LED light bulbs are approximately 80% efficient; only 20% of the energy is lost to thermal energy.

EXTENSIONS

Measuring other appliances or devices

Ask students to measure the economic and environmental costs of other appliances or devices. On the Economic and Environmental Cost of Using Appliances Activity Sheet, there are additional rows for

CO2 EMISSIONS BY SOURCE[3]



World Nuclear Association. (2022). Carbon Dioxide Emissions from Electricity. World Nuclear Association.

students to record their findings. You can have some students take a Kill A Watt Meter home to measure electrical devices in their homes.

Energy vampires (phantom loads)

Energy vampires are those electronic devices that we leave in the standby mode. In order to be ready to operate at all times, the electronic device, gadget, or appliance maintains a slow, reduced draw of electricity. The device still sucks energy when turned "off", hence the vampire reference. Even though the draw of the device is reduced, you are still paying for energy you aren't using. The bills can add up, particularly now with the rising cost of energy.

This undesired loss of electricity also is known as phantom load and some of the biggest culprits are electronics chargers. iPods, cell phones, and digital chargers have a steady current of energy flowing at all times–even when they say they are fully charged. Additionally, your television and DVD player, computers, auto-coffee maker and cordless phones all consume energy even when they are not in use. Computers can draw 7 watts (W) and microwaves can draw 1.2 W while in standby mode. The reason for standby is convenience, but now this convenience is coming at the cost of higher energy bills!

Consider this scenario: A young, four-person family with two cell phone chargers (1.2 W), two computers plugged in (7 W each), a microwave (1.2 W), a stereo (2.5 W), a DVD player (3 W), and two televisions (3.5 W each): has a total phantom energy load of 30.1 watts. This equates to .7224 kWh of energy per day or 264 kWh a year. In dollars this adds up to approximately $42.24 annually at the average rate of .16/kWh. And just remember, this is a conservative estimate. Often there are more phantom energy points than just the ones mentioned here.

Even though this is a relatively small portion of your total energy bill (approximately 5% of your total home energy consumption), the environmental and financial savings can accumulate, especially if everyone takes action. For the entire United States, this could add up to 65 billion kWh/year, which would save billions of dollars and tens of billions of pounds of carbon dioxide from entering the atmosphere. That's some powerful change.

Almost all electronic devices have a label describing how much power they consume when turned on. These labels vary greatly. To determine how many watts the device will use, multiply the output voltage and the current. Does this match the Kill A Watt meter reading? Why might these be different?

VOCABULARY

carbon dioxide (CO_2) – A colorless, odorless, non-combustible greenhouse-gas that contributes to climate change.

compact florescent (CFL) – A fluorescent light bulb the size of a standard incandescent light bulb. In a CFL, electricity vaporizes mercury gas, causing it to emit radiant energy which reacts with a coating inside the bulb, transforming UV waves to visible light.

energy – The ability to do work or to cause a change.

energy conservation – Reducing the overall amount of energy used through behavioral changes eg. turning lights off or dialing down the heat.

energy efficiency – Reducing the amount of energy used through improved technology. Examples include changing incandescent light bulbs to CFLs or LEDs and swapping out older appliances with Energy Star appliances.

incandescent – A bulb that makes light by heating a metal filament wire to a high temperature until it glows.

kilowatt (kW) – 1 kW = 1,000 W.

kilowatt-hour (kWh) – 1 kWh = 1,000 Wh.

LED (Light Emitting Diode) – A semiconductor device that emits visible light when an electric current passes through it.

megawatt (MW) – 1 MW = 1,000 kW = 1,000,000 W

megawatt-hour (MWh) – 1 MWh = 1,000 kWh

phantom load – The electric current consumed by a device when plugged in but switched to its labeled "off" position.

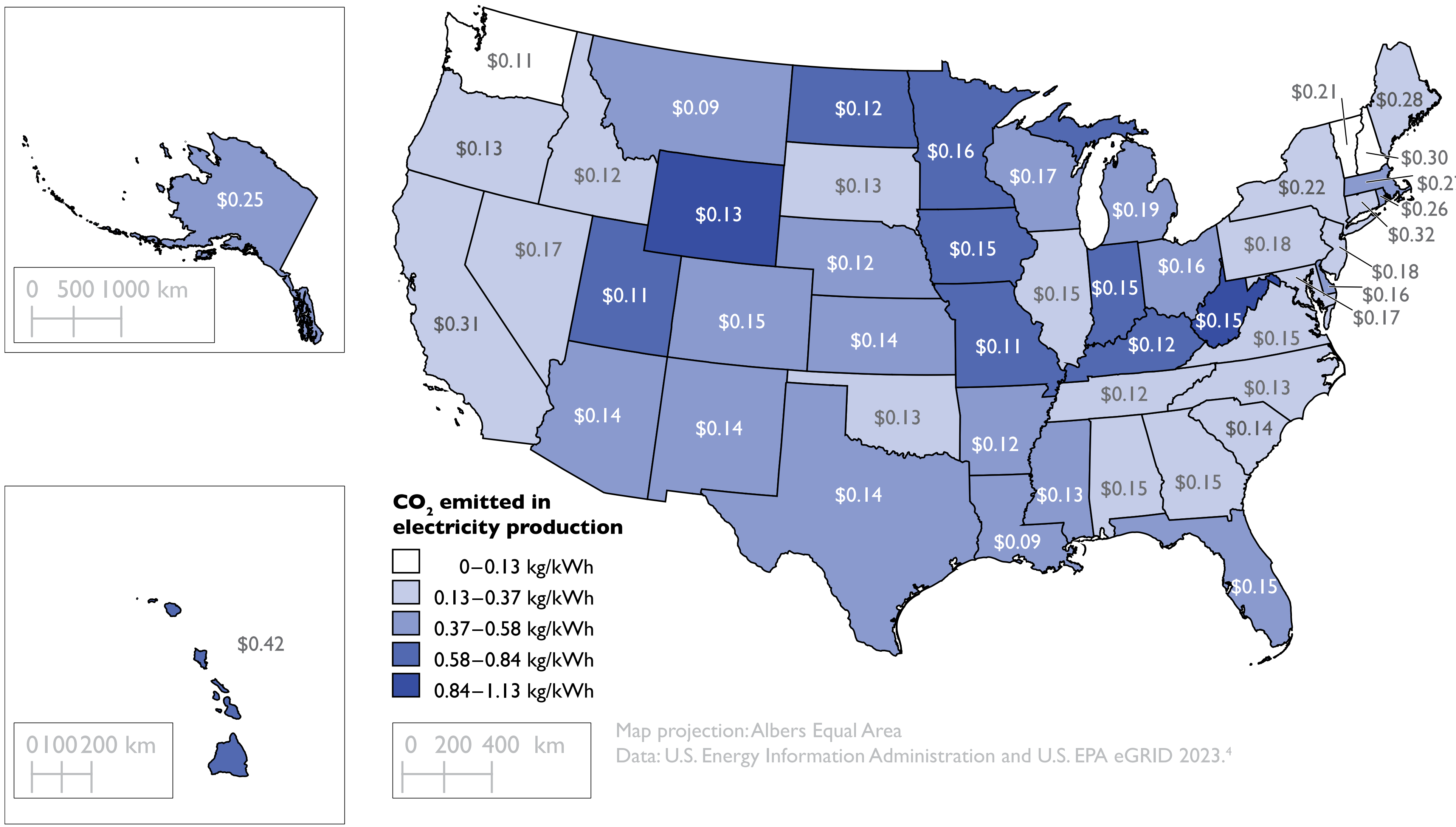
power – The amount of work done in a given amount of time.

watt – The measure of power consumed by an electrical appliance or device.

watt-hour – A unit of energy equal to 1 watt of power expended for 1 hour.

work – A measure of force times the distance through which it acts.

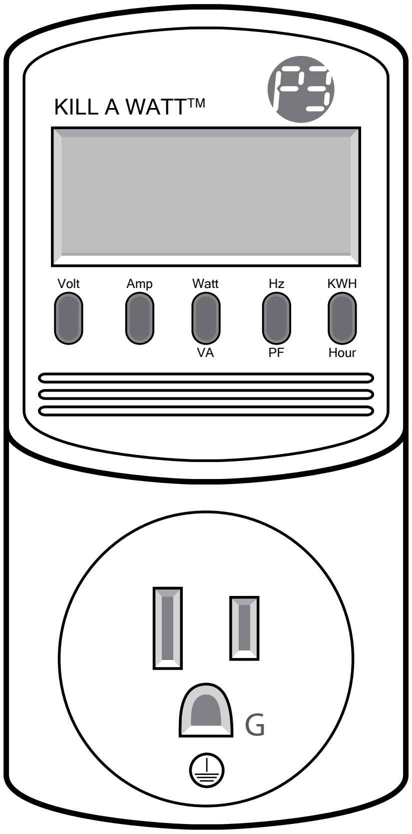
EMISSION INTENSITY AND RETAIL PRICE OF ELECTRICITY (PER KWH)

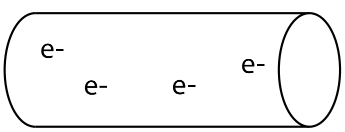


Map projection: Albers Equal Area
Data: U.S. Energy Information Administration and U.S. EPA eGRID 2023.[4]

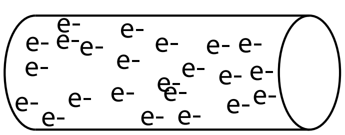
KILL A WATT METER

The Kill A Watt Meter is a device that lets you “see” how much power and/or energy an appliance in your house is using instantaneously or over a period of time. This page will help you understand some of the basic tools on this energy meter.

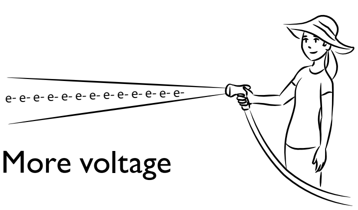




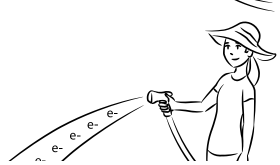
Less Current



More Current



More voltage



Directions: Plug the Kill A Watt Meter into a wall socket. Plug the device into the socket on the meter. The Watt button and kWh button are toggle switches. Make sure you have toggled each switch to make sure the readout is for watts (Watt/VA button) and kilowatt-hours (kWh/Hour button).

Volt button

When the Kill A Watt is plugged into the wall, the volt button will probably read somewhere around 120V. When you plug an appliance into the meter, it indicates the output voltage required to run your appliance.

Amp button

The AMP button will measure the flow of electric charge required to run your appliance. This value can vary greatly depending on the appliance you have plugged into the meter. When nothing is plugged in, this should read zero since no charge is flowing.

Watt button

The Watt button measures the power required to run your appliance. This is a measure of the movement of electrical energy required to make your device (blender, TV, etc.) function.

kWh

The kWh button measures the amount of energy used by your appliance.

In a water analogy, this would be equivalent to a bucket of water. It is a quantity of energy that can do a certain amount of work. If we had a lot of pressure (voltage) and a lot of water (current) moving through a hose, we could fill up the bucket very fast.

What is current?

Current (amperage) is the flow of electric charge in a conductor.

Using water as an analogy, we can think of this as the amount of water flowing through a tube. The higher the current, the more water that is moving in the tube. Low current would be similar to less water flowing in the same size tube.

What is voltage?

A negative charge will attract a positive charge, and invisible fields of voltage exist between the charges, kind of like magnetic fields. Voltage causes the attraction between opposite charges; we can quantify this attraction with a simple multimeter.

Using water as an analogy, we can also think of voltage like water pressure. Low voltage would resemble water under low pressure. High voltage would resemble water under high pressure. The amount of water is not so important; it is the pressure of the water that matters.

READING PASSAGE: ENERGY EFFICIENCY

Energy efficiency is a very broad term referring to the many different ways we can get the same amount of work (light, heat, motion, etc.) done with less energy. It covers efficient cars, energy saving lighting, improved industrial practices, better building insulation and a host of other technologies. Since saving energy and saving money often amount to the same thing, energy efficiency is highly profitable.

Efficient energy use, sometimes simply called energy efficiency, is reducing the amount of energy required to provide products and services. For example, insulating a home allows a building to use less heating and cooling energy to achieve and maintain a comfortable temperature. Installing compact fluorescent or LED lights reduces the amount of energy required to attain the same level of illumination compared to using traditional incandescent light bulbs. Compact fluorescent light bulbs use two-thirds less energy and may last 6 to 10 times longer than incandescent lights.

There are various motivations for improving energy efficiency. Reducing energy use reduces energy costs. Reducing energy use is also seen as a key solution to the problem of reducing harmful emissions generated by coal-burning power plants. According to the International Energy Agency, improved energy efficiency in buildings, industrial processes, and transportation could reduce the world's energy needs in 2050 by one third, and help control global emissions of greenhouse gases.

Since we currently generate about half of our electricity in the United States from coal-fired power plants, the choices we make about electricity consumption have a significant impact on the amount of carbon dioxide (CO_2) released into the atmosphere. CO_2 is one of the major gases that traps heat in our atmosphere. Every kilowatt-hour (kWh) of electricity that we consume in the US—approximately $0.16 worth of electricity—generates 0.39 kgs CO2e (e signifies the amount of CO2 which would have an impact on global warming). The amount of CO_2 per kWh changes in different parts of the country, due to the major sources of electrical energy.

STATE	KILOGRAMS CO2 PER KWH	DOMINANT FUEL SOURCES
Alabama	0.35	coal, nuclear, gas
Alaska	0.54	gas, oil, hydro
Arizona	0.31	coal, gas, nuclear
Arkansas	0.48	coal, nuclear, gas
California	0.23	gas
Colorado	0.55	coal, gas
Connecticut	0.25	nuclear, gas
Delaware	0.57	coal, gas
Washington, DC	0.53	oil
Florida	0.39	gas, coal
Georgia	0.35	coal, nuclear
Hawaii	0.70	oil
Idaho	0.15	hydro
Illinois	0.31	nuclear, coal
Indiana	0.75	coal
Iowa	0.75	coal
Kansas	0.40	coal

Kentucky	0.80	coal, gas
Louisiana	0.46	gas, nuclear
Maine	0.21	gas, hydro, wind
Maryland	0.31	nuclear, gas
Massachusetts	0.43	gas, bimass, solar
Michigan	0.48	nuclear, coal, gas
Minnesota	0.39	nuclear, coal, gas, wind
Mississippi	0.38	gas, nuclear
Missouri	0.77	coal, wind
Montana	0.51	coal, hydro
Nebraska	0.56	coal, wind
Nevada	0.33	gas, solar
New Hampshire	0.13	nuclear, gas
New Jersey	0.24	nuclear, gas
New Mexico	0.49	coal, gas, wind
New York	0.23	gas, nuclear, hydro
North Carolina	0.32	gas, nuclear, coal
North Dakota	0.64	coal, wind
Ohio	0.55	coal, gas, nuclear
Oklahoma	0.34	gas, wind
Oregon	0.14	hydro, gas
Pennsylvania	0.33	gas, nuclear
Rhode Island	0.38	gas
South Carolina	0.26	nuclear, coal, gas
South Dakota	0.15	hydro, wind
Tennessee	0.34	nuclear, coal, gas
Texas	0.43	gas, coal, wind
Utah	0.70	coal, gas
Vermont	0.004	hydro, wind, solar
Virginia	0.29	nuclear, gas
Washington	0.10	hydro, gas
West Virginia	0.88	coal
Wisconsin	0.57	coal, gas, wind
Wyoming	0.84	coal, wind

Energy efficiency and renewable energy, such as wind power, are said to be the twin pillars of a sustainable energy future.[6] In many countries, energy efficiency is also seen to have a national security benefit because it can reduce the need for energy imports (i.e. petroleum and coal) from foreign countries and may slow down the rate at which domestic energy resources are depleted.

Modern energy-efficient appliances, such as refrigerators, dishwashers, and clothes washers, use significantly less energy than older appliances. Current energy-efficient refrigerators, for example, use 40% less energy than conventional models did in 2001.

Energy conservation is broader than energy efficiency and includes active efforts to decrease energy consumption, such as behavioral change. Examples of conservation without efficiency include lowering the temperature on the thermostat during the winter, turning off the light(s) when leaving a room, and riding a bike or walking instead of driving a car.

CAREER PROFILE: JIM BROWN, ENERGY AUDITOR

I help people save money and protect the environment by showing them ways to save energy in their home or work. As an energy auditor, I examine how energy is being used in a building and then make energy efficiency and conservation recommendations to the people who live or work in the building. I might suggest that they buy new, more energy-efficient appliances and equipment to replace older, less efficient models. There are also lots of different conservation strategies that I tell people about.

One of the most common things that I will do in any building is to switch all of the inefficient, incandescent light bulbs to compact fluorescents or other highly efficient lighting technologies. Another lighting technology that I really like is the passive solar technology that allows the use of daylight, which means letting sunlight into the building instead of turning on electric lights. When a building is designed properly, there often is little need for lights during the daytime.

When I perform an energy audit, I use specialized tools, such as Kill A Watt Meters, blower doors, air flow meters, and infrared cameras to evaluate how much energy a building is using. Kill A Watt meters measure how much electricity an appliance uses when it is on. They are also very helpful in finding energy vampires and phantom loads—appliances that use energy even when they are turned off. My favorite tool is a blower door, which is used to depressurize a building. By forcing air out of the building with the blower door, I can then find where air is leaking into or out of a building. Air leaks can account for a large percentage of the energy used for heating and cooling a building. Infrared cameras can help me pinpoint exactly where the leaks are so that I can come up with a plan to fix them.

Energy auditing is a fun job that involves science, technology, and a good deal of problem solving. The most rewarding parts of the job is knowing that I'm doing something good for the environment and helping people save money. Growing concerns about climate change, energy security, and fuel prices mean that there's more and more work for energy auditors. It's a good career to consider.

Name_______________________________ Date_____________ Class_______

THE ECONOMIC AND ENVIRONMENTAL COST OF USING APPLIANCES ACTIVITY SHEET

State ______ Electricity cost ($/kWh) ______ State's major sources of energy ________________ Emission intensity (kg of CO_2/kWh) ____________

US average cost: kWh: 0.1 US average intensity: 0.62 kg of CO_2/kWh

Appliance/Device	Measured power use (W)	Time Appliance on per day (hours)	Energy used in one day (kWh)	Energy Use in a Year (kWh)	Yearly Cost (with updated information)	CO_2 produced to in one year (use your state data)
Example: (20" LCD Television)	120	4 hours	480Wh = .48 kWh	.48 kWh × 365 = 175.2 kWh	175.2 kWh × $0.10 = $17.52	175.2 kWh × 0.39 kg/kWh = 240.02 kg/kWh

ENERGY EFFICIENCY ACTIVITY WORKSHEET

1. Define power (use examples):

2. Define energy (use examples):

3. Unit Conversions (Remember, 1 kW=1,000W and 1 MW=1,000,000 W)
   a. 1500 W = _____________ kW
   b. 500 kW = _____________W
   c. 1000 kW = _____________ MW

Using data from the worksheet:

4. Which light bulb uses the most power?

5. Which light bulb uses the most energy?

6. Name one appliance that would be called an energy vampire. Why is it using energy even when it seems to be turned off?

7. How much energy would the following devices use?
   a. 15-watt compact fluorescent that is on for 10 hours: _______________Wh
   b. 60-watt incandescent bulb that is on 5 hours: _______________Wh
   c. 1200-watt oven that is used for 1.5 hours: _______________Wh

8. Which uses more energy in one month (30 days)?
   a. Energy vampire that uses 5 watts for 24 hours a day
   b. 100-watt stereo that is used for 1 hour each day
   c. 1000-watt toaster that is used for 0.1 hour each day

9. What is one way you can save energy at home through conservation?

10. What is one way you can save energy at home through efficiency?

11. Answer the following questions based on the graph at the end of the worksheet.
    a. People in what country use the most electricity per year?

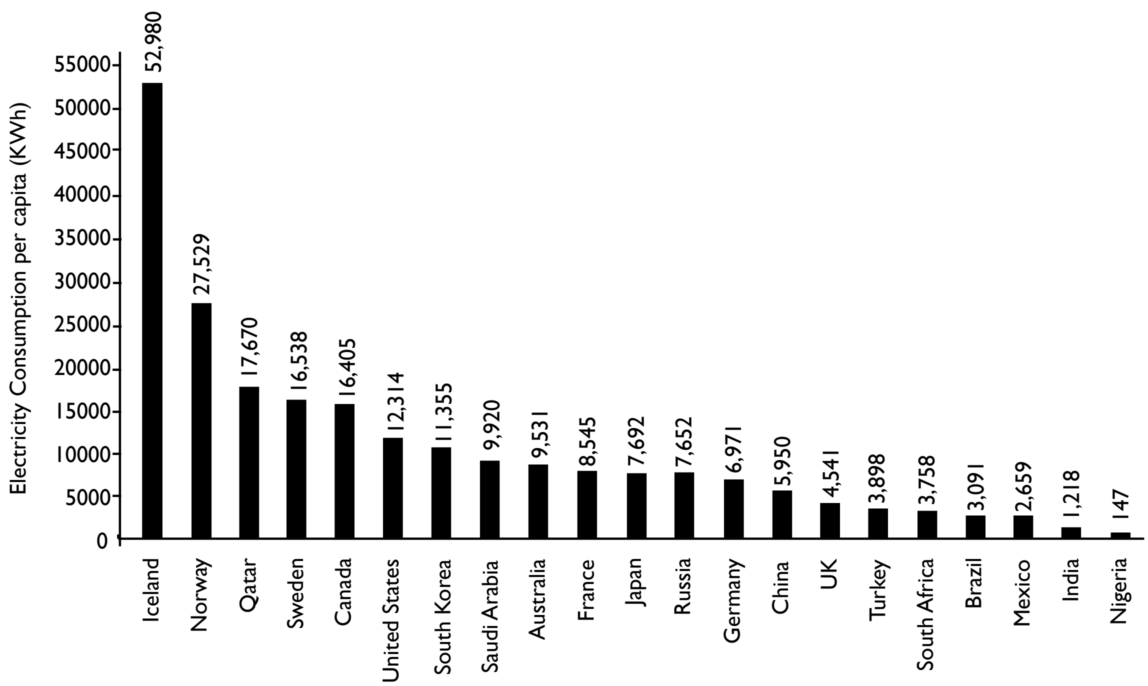
    b. People in what country use the least electricity per year?

    c. Why might there be such great differences in electricity use among different countries?

d. Do you think that people in Europe (such as France, Germany, and the United Kingdom) have a lower standard of living than people in the United States and Canada? Why?

e. How many people in India could live their daily lives using the electricity consumed by one person in the United States?

PER CAPITA ANNUAL ELECTRICITY USE, AROUND THE WORLD[7]



(Data Source: Our World in Data, 2021)

Because of Iceland's industrial sector and small population of 320,000 people, the country has the highest electricity consumption per capita in the world. This is similar for Norway's manufacturing industry and its need to use electricity for heating.

In India, a lack of investment in the energy sector and use of traditional fuels like charcoal make energy consumption per capita much lower compared to other countries. Nigeria also has poor energy infrastructure, as well as a lack of water and gas supply, making electricity consumption very low.

1. Define power (use examples)

   The amount of work done in a given amount of time. Students may have many examples.

2. Define energy (use examples)

   The ability to do work or to cause a change. Students will have many examples.

3. Unit Conversions (Remember, 1 kW=1,000 W and 1 MW=1,000,000 W)

   a. 1500 W = 1.5 kW
   b. 500 kW = 500,000 W
   c. 1000 kW = 1 MW

Using data from the worksheet:

4. Which light bulb uses the most power?

   Incandescent

5. Which light bulb uses the most energy?

   Incandescent

6. Name one appliance that would be called an energy vampire. Why is it using energy even when it seems to be turned off?

   Student observations. Any device that is consuming power when it is turned "off" can be called an energy vampire. It may be using energy to stay warm so that it can turn on quickly or may not be designed to use electricity efficiently. A few examples include: cell phone chargers, VCRs and DVD players, and TVs.

7. How much energy would the following devices use?

a. 15-watt compact fluorescent that is on for 10 hours	*150 Wh*
b. 60-watt incandescent bulb that is on for 5 hours	*300 Wh*
c. 1200-watt oven that is used for 1.5 hours	*1800 Wh*

8. Which uses more energy in one month (30 days)?

a. Energy Vampire that uses 5 watts for 24 hours a day	*3600 Wh*
b. 100-watt stereo that is used for 1 hour each day	*3000 Wh*
c. 1000-watt toaster that is used for 0.1 hour each day	*3000 Wh*

9. What is one way you can save energy at home through conservation?

   Possible answers include:

   Turning off lights when you are going out of the room

   Take shorter showers

   Energy conservation is changing your behavior in order to save energy.

10. What is one way you can save energy at home through efficiency?

    Possible answers include:

    Using CFL bulbs

    Installing a programable thermostat

    Installing a low-flush toilet

    Using Energy Star appliances

All of these calculations/answers below are based off of the per-capita information given on the previous page.

11. Answer the following questions based on the graph at the end of the worksheet.

    a. People in what country use the most energy per year?

    Iceland

    b. People in what country use the least energy per year?

    Nigeria

    c. Why might there be such great differences in energy use among different countries?

    People in affluent countries generally have larger houses, more electronic devices, and they tend to waste more energy. Also people from colder climates tend to use more energy for heating and lighting during winter months.

    d. Do you think that people in Europe (such as France, Germany, and the United Kingdom) have a lower standard of living than people in the United States and Canada? Why?

    Student observations will vary, but generally people in Europe have lights, heat, and all the electricity they need to lead very modern lives. It is all about doing the same with less and improving efficiency. One place to read more about how much energy we could save and still lead very modern lives is on the Department of Energy's website (https://www.energy.gov/eere/energy-efficiency-buildings-and-industry)

    e. How many people in India could live their daily lives using the energy consumed by one person from the United States?

    Approximately 83 people. In the U.S., the average person consumes 12,314 kWh of energy each year. In India, the average person consumes 1,218 kWh of energy per year.

$$\frac{\text{U.S. } 12314 \text{ kWh}}{\text{India } 1218 \text{ kWh}} = 10.11$$

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