Which Do You A-Door?

Comparing the Energy Needed to Make Wood and Steel Doors

Meet the Scientists

Melissa Huff, Chemical Engineer: My favorite science experience was when my physics classmates in college and I watched our professor dip a rubber ball into liquid nitrogen. He then dropped it, and the ball shattered. This is due to the temperature of the liquid nitrogen (-196 degrees Celsius or -321 degrees Fahrenheit). As you cool a gas down, the atoms move less and less rapidly. Eventually, the attractive forces between the atoms hold them together as a liquid. If you cool the rubber ball down in the liquid nitrogen, the atoms in the rubber become locked into position so they can't move past each other. The ball becomes very brittle, and it can easily shatter. ▼

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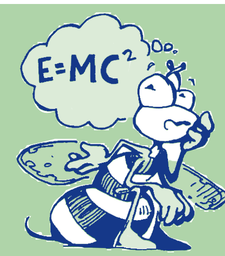
Janet Stockhausen, *Patent* Attorney: My favorite science experience is working with inventors. Inventors are excited about their inventions, and they love to show how their invention works. They also love to explain why it works, and why it is better than everything else like it. Inventors like to talk about the potential for making the world a better place. It is really fun to work with them. I love hearing the enthusiasm in their voices.

Robert Ross, Wood Engineer: My favorite science experience is working on research projects that ultimately result in technical advances that help people. For example, scientists like me do work that influences all of the building codes in the United States. Building codes directly affect how homes, schools, churches, gymnasiums, and other buildings are constructed. The research you will read about in this article focused on understanding the differences between wood and steel doors—ultimately, it will result in beautiful doors, made of wood that will provide the security of steel doors. ▶

Thinking About Science



When scientists want to compare things, they must use a common language. In this research, the scientists wanted to compare the environmental impact of making two different kinds of doors. The scientists went to the International Organization for Standardization (**stan** dürd uh **za** shun) for help. This organization creates *standards* for a wide variety of products and processes. The organization reported that two products can be compared if they provide the same *utility* to a *consumer*. The scientists decided that they could compare two different doors if both of those doors could be used to enter a house. Based on this standard, could you compare the utility of a plastic and metal fork? Why or why not?

Glossary

patent (**pat** ent): A document giving the exclusive right to make, use, or sell an invention for a number of years.

standards (**stan** dürds): Things set up as a rule or model with which other things like it are to be compared.

utility (u **til** uh te): The quality of being useful.

consumer (kän **sum** ür): A person or thing that consumes or uses something.

manufacture (**man** u **fak** chür): The making of goods or articles.

natural resources (**na** cha rôl **re** sôrs es): Supplies of things in nature that take care of a human need, such as oil, wood, or water.

fiberglass (**fib** ür glas): Glass in a fiber form used for making products, such as insulation.

partial (**pär** shul): Of a part, or in only a part.

database (**dat** uh bas): A large collection of information stored in a computer and organized so that it is available for use.

average (**av** rij): The usual kind or amount. The number gotten by dividing the sum of two or more quantities by the number of quantities added.

extraction (ek **strak** shun): The act of extracting or pulling out by effort.

emissions (e **mish** ens): Something discharged or sent out.

solid waste (**saw** lid wast): Any solid or semi-solid liquid, or contained gaseous materials discarded from industrial, commercial, mining, or agricultural operations; and from community activities, including garbage.

waterborne (**wa** tür bôrn): Carried in or by water.

kiln (kiln): A furnace or oven for drying bricks, pottery, or other items.

molten (**môl** tun): Melted by heat.

carbon dioxide equivalent (**kär** bun di **ox** id e **kwiv** uh lent): A quantity that describes, for a given greenhouse gas, the amount of carbon dioxide that would have the same global warming potential when measured over a specific time period.

unit of measurement (**u** nit of **mezh** ür ment): A standardized quantity of a physical property, such as inches, meters, kilograms, etc.

Pronunciation Guide

a	as in ape	ô	as in for
ä	as in car	u	as in use
e	as in me	ü	as in fur
i	as in ice	oo	as in tool
o	as in go	*ng*	as in sing

Accented syllables are in **bold.**

Thinking About the Environment

Every product you buy was produced using energy. Every process used to create products also creates waste. In this research, the scientists wanted to compare the amount of energy used and amount of waste created in the *manufacture* of two different types of doors. This kind of comparison is called a life-cycle inventory (**figure 1**). Most life-cycle inventories include the amount of energy used and waste created from when the raw materials are gathered to make the product to when a consumer no longer wants and disposes of the product. In this research, the scientists were interested only in the energy used and waste created until the time the doors were ready to be shipped to a store.

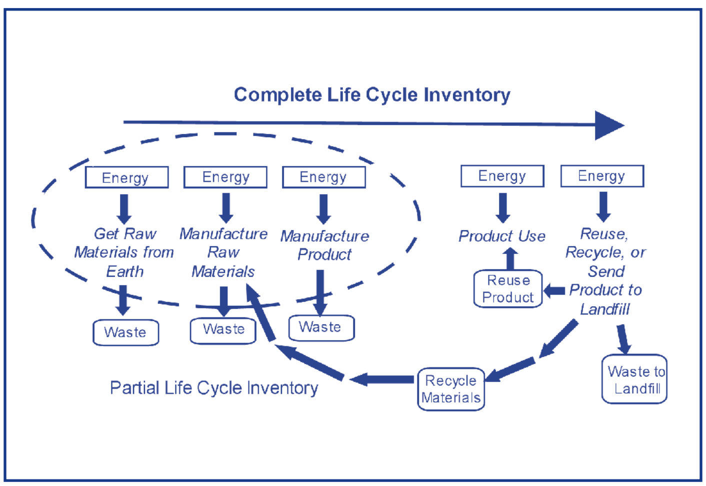


Figure 1. Life-cycle inventory. This shows the entire life-cycle inventory process. The part of the life-cycle inventory used in this research to compare the utility of two different kinds of doors is also shown. The result of a life-cycle inventory is a measurement of the environmental impact of one or more products. (Image courtesy of Franklin Associates http://www.fal.com)

Figure 2. The Forest Products Laboratory.

Introduction

The Forest Products Laboratory, located in Madison, Wisconsin, is a place where scientists work to develop wood products for human use (**figures 2 and 3**). The scientists at this laboratory develop processes for making wood products that use as few *natural resources* as possible. One of the wood products they developed was a wood door. The door was made using a process to strengthen the wood by including a small amount of *fiberglass*. The fiberglass made the wood door strong enough to be used in place of a steel door.

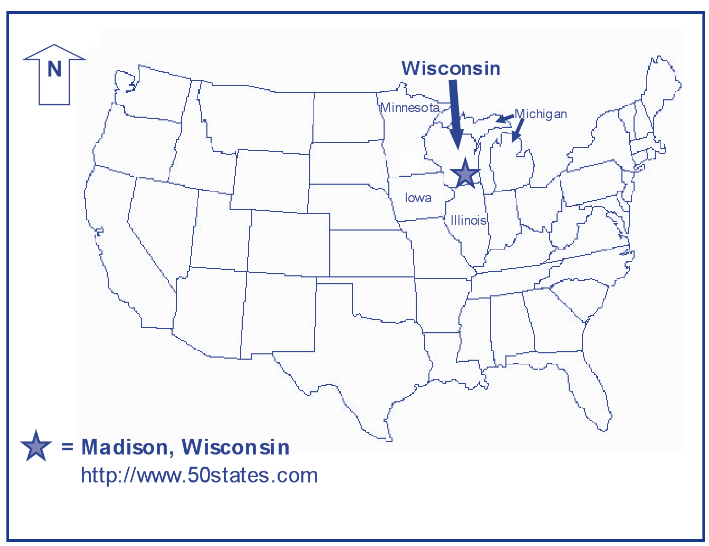


Figure 3. Madison, Wisconsin.

The scientists believed that wood doors and steel doors provide the same utility to a consumer (**figures 4 and 5**). If that is the case, they wondered which door would use less energy and create less waste up to and including the manufacturing process. To answer their question, the scientists conducted a *partial* life-cycle inventory to compare the two doors. In this article, the manufacturing process includes gathering and processing the raw materials for each door. As an example, for the wood door this includes harvesting the tree and transporting it to a mill.

Reflection Section

- In your own words, state the question the scientists wanted to answer.
- Where do people get the raw materials they need to manufacture products?

Method

The scientists first had to identify which raw materials are needed for a wood door made with fiberglass and which materials are needed for a steel door. They then had to identify where those raw materials come from. They made a diagram of the process used to manufacture a steel door and a wood door (**figures 6a and 6b**).

The scientists also had to identify how much energy is used for gathering raw materials and manufacturing each door, and how much waste is created in each process.

The scientists collected their information from a special *database*. The database is kept by a company that does a variety of life-cycle inventories. The scientists collected information about the *average* energy used to manufacture each kind of door. The categories of information collected were:

1. *Extraction*, transportation, and processing the fuels used in all the manufacturing processes.

Figure 4. Wood door. Photo courtesy of Lowe's.

Figure 5. Steel door. Photo courtesy of Lowe's.

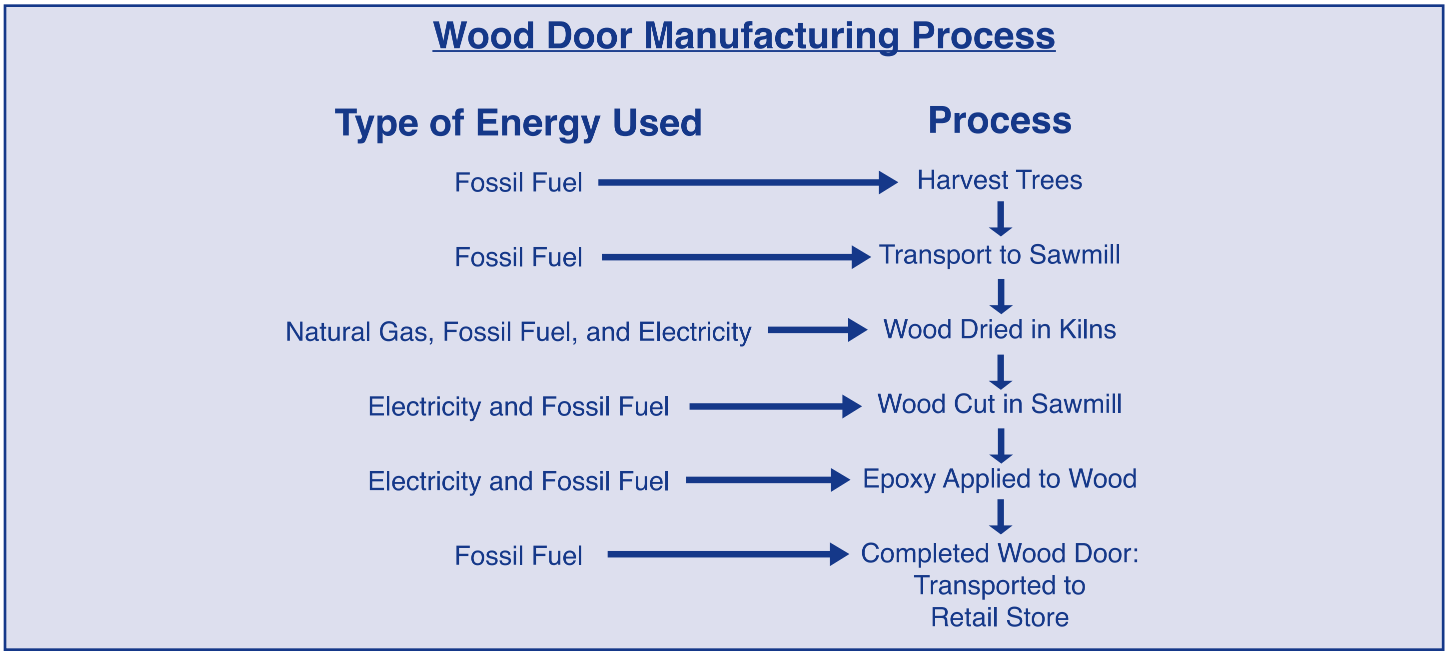


Figure 6a. A diagram, or flow chart, of the manufacturing process of a wood door.

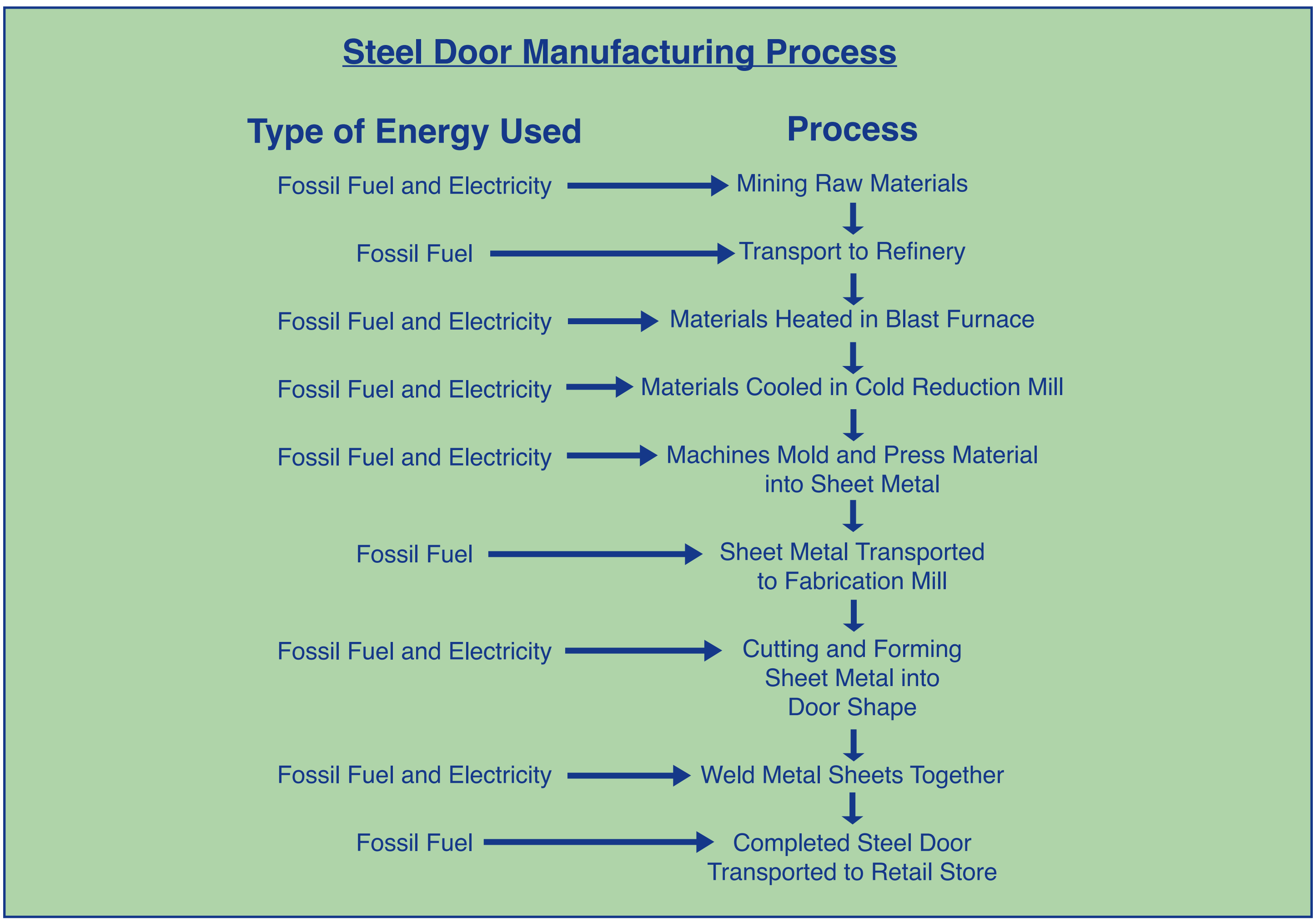


Figure 6b. A diagram, or flow chart, of the manufacturing process of a steel door.

2. Extraction, transportation, and processing the raw materials used in all the manufacturing processes.

The scientists also collected information about the average amount of waste products, including *emissions*, resulting from the manufacture of each kind of door. The categories of information collected were:
1. Air emissions.
2. *Solid waste*.
3. *Waterborne* waste.

Before a wood door can be manufactured, the raw materials for the door must be collected. For a wood door, trees are the main raw material used. When trees are harvested, energy is used and pollutants are produced. Pollutants are produced from the cutting equipment and machinery, and include more than air emissions (**figure 7**). Soil erosion can result in water pollution in the form of soil particles in the water. The cut logs are taken to a sawmill, the bark is taken off, the logs are cut into boards, and then dried in a *kiln*. The wood door is strengthened with fiberglass. All of these processes require energy and result in environmental emissions.

Figure 7. Wood harvesting operation.

Before a steel door can be manufactured, mining for raw materials must be done. Mining for iron ore, zinc, limestone, and coal is necessary to manufacture steel (**figures 8a and 8b**). Most of these materials are placed in a blast furnace to produce a substance called pig iron. The *molten* pig iron is further heated and poured into molds, where it is cooled and made

Figures 8a and 8b. Surface mining operations. Photos courtesy of Peter Robey Mining Photography.

into sheet metal. The sheet metal is galvanized (**gal** van izd) by being coated with a thin layer of zinc. This process protects the sheet metal from rust. During manufacture, the inside of steel doors are filled with a material, a form of polystyrene (**paw** le **sti** ren), like Styrofoam. All of these processes require energy and produce environmental emissions.

When steel doors are manufactured, the sheet metal must be cut, welded, stamped, and the door filled with polystyrene. Then the door must be painted. While these processes create a lot of emissions and solid wastes, some of the solid waste products can be recycled.

The scientists calculated how much energy is used and how much emissions are created in the manufacture of each door. The information they collected included:

1. Number of airborne substances released.
2. Number of waterborne substances released.
3. Total energy use in gigajoules (**gig** uh julz).
4. Solid waste in kilograms.
5. Greenhouse gas emissions in kilograms of *carbon dioxide equivalents*.

Reflection Section

- The scientists included the energy used and emissions produced when the raw materials were collected, as well as the manufacture of each door. Why do you think they included the gathering of raw materials in the life-cycle inventory?
- Do you think the scientists found it takes more energy to manufacture a wood door or a steel door? Why?

Findings

The scientists calculated amounts for 44 airborne emissions released to the environment, including 3 greenhouse gases. They also calculated amounts for 32 waterborne wastes released to the environment, as well as solid wastes and the amount of energy used in the manufacturing process. **Tables 1–5** show the results of their research.

Table 1. Number of airborne emissions produced by the manufacture of a wood door and a steel door.

Airborne emissions for which:	Number of emissions
Steel door was higher	31
Emissions were reported for steel door but not for wood door	5
Steel door was lower	7
Emissions were reported for wood door but not for steel door	0
No difference found	1

Table 2. Number of waterborne wastes produced by the manufacture of a wood door and a steel door.

Waterborne wastes for which:	Number of emissions
Steel door was higher	28
Emissions were reported for steel door but not for wood door	4
Steel door was lower	0
Emissions were reported for wood door but not for steel door	0
No difference found	0

The amount of energy used in the manufacture of a steel door and a wood door was measured in gigajoules (**GJ**) (**table 3**). One GJ is equal to about 278 kilowatt hours (kWh), or 238,000 nutritional calories. The joule is a member of the international system of units (SI), the modern form of the metric system.

Table 3. Total amount of energy, measured in GJ, used in the manufacture of a wood door and a steel door.

	Total energy (GJ)
Steel door	2.17
Wood door	0.10

The amount of solid waste produced in the manufacture of the doors was measured in kilograms (kg). **Table 4** shows the amount of solid waste produced in the manufacture of each door, measured in kg.

Table 4. Amount of solid waste produced in the manufacture of a wood door and a steel door.

	Total amount of solid waste produced (kg)
Steel door	22.3
Wood door	0.51

Number Crunches

- Let's say the average daily energy use in a home is 15 kWh. How many days will it take before the amount of energy used in that home is equal to the total amount of energy used to manufacture a steel door? How many days will it take to equal the amount of energy used to manufacture a wood door? (Remember: 1 GJ is equal to about 278 kWh.)
- While doing vigorous exercise such as running, an adult burns about 100 nutritional calories each hour. How many hours will it take to burn 1 GJ of energy? How many days of vigorous exercise will it take the adult to burn 1 GJ of energy? How many days of vigorous exercise will it take for the adult to burn the amount of energy used in the production of a steel door and a wood door? (Remember, 1 GJ is equal to 238,000 nutritional calories.)
- One kilogram is equal to about 2.2 pounds. Create your own **table 4** using pounds, instead of kilograms, as the *unit of measurement*.

Table 5 presents the potential of three greenhouse gases to contribute to global warming during the manufacture of each door. This amount is expressed in relation to the global warming potential of carbon dioxide over a 100-year period, which is set at 1. In other words, if another greenhouse gas has a value of 2, it has twice the global warming potential of carbon dioxide over a 100-year period. The gases listed in **table 5** are the three largest contributors to global warming.

Table 5. The amount of greenhouse gases produced during the manufacture of wood and steel doors.

Gas	Global warming potential of gas	Steel door (kg of carbon dioxide per door)	Wood door (kg of carbon dioxide per door)
Carbon dioxide	1	135	5.11
Methane	23	5.87	0.13
Nitrous oxide	296	0.10	0.0051
TOTAL	No Total	141	5.25

Reflection Section

- Examine **tables 1–5**. What conclusion can you make about the production of a steel door in comparison with the production of a wood door?
- Based on the findings you have just read, what would you predict about the environmental impact of manufacturing a steel table compared with manufacturing a wood table?

Discussion

According to this research, the manufacture of a steel door results in more air emissions, more waterborne pollutants, and more solid waste than the manufacture of a wood door. A steel door also requires more energy in its manufacturing and results in a greater potential to contribute to global warming. The manufacture of a steel door, in fact, consumes 21 times the amount of total energy and produces over 40 times the amount of solid waste compared to the manufacture of a wood door.

Reflection Section

- This life-cycle inventory showed that more energy is used and more waste produced in the manufacture of a steel door. What might be one advantage of using a steel door instead of a wood door in your home? Do you think this advantage of using a steel door outweighs the disadvantage of its greater environmental impact? Why or why not?
- If you were employed by a home improvement store in your community, what would you tell a homeowner who has come into your store wanting to buy a new door for his or her home?

From: Knight, L., Huff, M., Stockhausen, J. I., and Ross, R. J. 2005. Comparing energy use and environmental emissions of reinforced wood doors and steel doors. *Forest Products Journal*, 55 (6): pp. 48-52, http://www.fpl.fs.fed.us/documnts/pdf2005/fpl_2005_knight001.pdf.

FACTivity

Time Required

One class period

Materials Needed

1. One large raw potato
2. One 10-ounce bag of plain potato chips
3. One blank sheet of paper and a pencil for each group

The research question you will answer by doing this FACTivity is: "Does a baked potato or a 10 ounce bag of potato chips require more energy when it is produced for human consumption?" This question is similar to the question asked by the scientists in this research, except the scientists compared two doors instead of two kinds of potatoes. You may want to re-read the last paragraph of the "Introduction" to remind you of the scientists' research question.

When the scientists compared doors, they compared doors of equal utility. This means that both doors could serve the same purpose for an individual. When you compare two kinds of potatoes, are you comparing products that serve the same purpose for an individual? How do the two types of products (doors and potatoes) compare?

Method

The method you will use to answer the research question is:

Consider the following: Just as doors have a premanufacturing stage and a manufacturing stage, the two potato products have a preprocessing and a processing stage. Potatoes must be planted, grown, dug, and transported to a facility for processing before they can be shipped to a supermarket shelf.

In small groups, brainstorm the steps that must be taken before potatoes are shipped to a facility for processing. For both kinds of potato products, this preprocessing stage will be the same. Once the potatoes get to their facilities for processing, each type of potato will be processed differently. Write down the steps that must be taken, and identify the kind of energy needed for these steps.

Example:

STEP	ENERGY NEEDED
Plow field before planting	Diesel fuel for machinery
Plant potatoes	Diesel fuel for machinery

Once you have done this, you must now consider what kind of processing is needed to prepare each potato product and transport it to a store. In the case of the potato, processing may only include cleaning, sorting, bagging, and transporting. It takes more steps to create potato chips, even before they are placed in bags for shipping to stores. Although you may have never been to a potato chip processing plant, see if your group can imagine what steps must be taken from the time a potato arrives at the plant to the time it leaves the plant as a bag of potato chips. Use the same format to record the steps that you used when you imagined the steps required to get a potato to the processing plant. Remember to do this for a potato, as well as for the potato chips.

Remember that you must consider all steps needed before human consumption for both kinds of potatoes.

You should now have a good idea of the steps and types of energy required to process a potato and a bag of potato chips for human consumption.

As a class, compare the steps each group has developed for each type of potato. Discuss the amount of energy that might be required by each type of potato product. Although you will not know exactly how much energy each type of potato product requires for processing, you should have a good idea of which type of potato processing requires more energy.

Now answer your research question: Which potato product requires more energy to be processed for human consumption?

FACTivity: Go Outdoors

Time required

One class period

Materials needed

One 12″ new or used clay pot
One 12″ new or used clay saucer
One 12″ new or used plastic pot
One 12″ new or used plastic saucer
One new or used metal trash can lid (with no holes)
One large new or used sturdy plastic bucket
Acrylic sealant (brush-on or spray can)
Paint brush (if using brush-on sealant)
Heavy-duty outdoor glue
24″ rope
Two bricks (one preferably with holes)
Flat rock, about 4″ in diameter

In this FACTivity, you will answer the question: How does the energy use involved in the construction of three homemade bird baths compare when they are constructed?

This FACTivity involves a partial life-cycle inventory. The research article you read described a partial life-cycle inventory involving the manufacturing process up to production of the product. Complete life-cycle inventories include use, reuse, recycling, or disposal of the product. You will construct three bird baths from either new or recycled materials.

Method

The method you will use to answer the research question is:

Your class will construct three different bird baths using either new or used materials. After construction, each bird bath will be compared on the basis of whether its construction involved new or recycled materials.

Birdbath #1: Clay pot, clay saucer, sealant
Birdbath #2: Plastic pot, plastic saucer, glue, flat rock
Birdbath #3: Plastic bucket, metal trash can lid, bricks, rope

Divide into three groups. Each group will construct one birdbath. Construction and placement should occur at about the same place. Place your birdbaths in an area away from bushes or other low vegetation, but close to a tree if possible. Low vegetation may hide predators, and trees will provide a place for birds to perch.

Birdbath #1:

1. The day before, seal the clay saucer with sealant.
2. Turn the clay pot over and position it where you want to place the birdbath.
3. Place the clay saucer on the over-turned pot.
4. Fill the saucer with water. Place fresh water in the saucer every day.

Birdbath #2:

1. Turn the plastic pot over and position it where you want to place the birdbath.
2. Glue the plastic saucer on the over-turned pot.
3. Place a flat rock in the center of the birdbath for stability.
4. Fill the saucer with water. Place fresh water in the saucer every day.

Birdbath #3:

1. Place the plastic bucket where you want to place the birdbath. This birdbath should be placed where there is complete shade during the hottest part of the day.
2. Place one of the bricks in the bottom of the bucket for stability.
3. Measure the bucket's height and subtract 4 inches. Cut the rope to this length.
4. Tie one end of the rope to the handle on the trash can lid.
5. Tie the other end of the rope around the second brick.
6. Place the trash can lid upside down on the bucket, letting the brick dangle inside the bucket. The brick will provide stability for the trash can lid.
7. Fill the trash can lid with water. Place fresh water in the lid every day.

Now that you have made your birdbaths, it is time to compare them. Each group will assess its own birdbath. This can be done inside the classroom.

Make a list of the materials used for your birdbath. Note if the material is new or used. You may use the example below to create your chart.

Type of Birdbath:

MATERIAL	NEW OR USED?	NUMBER OF POINTS
Clay pot	New	
Trash can lid	Used	
Glue	New	
TOTAL POINTS	-----------------	

If the material used is new, give it one point. If the material is used, give it a zero. Now add the points for your birdbath. If your birdbath was built entirely from used materials, it should have received zero points.

As a class, compare the point values of each birdbath. What do those values tell you about the energy needed to construct each birdbath? What does this comparison tell you about the energy involved in the use of new and used materials for construction?

If you are a Project Learning Tree-trained educator, you may use Activity #69: "Forest for Trees."