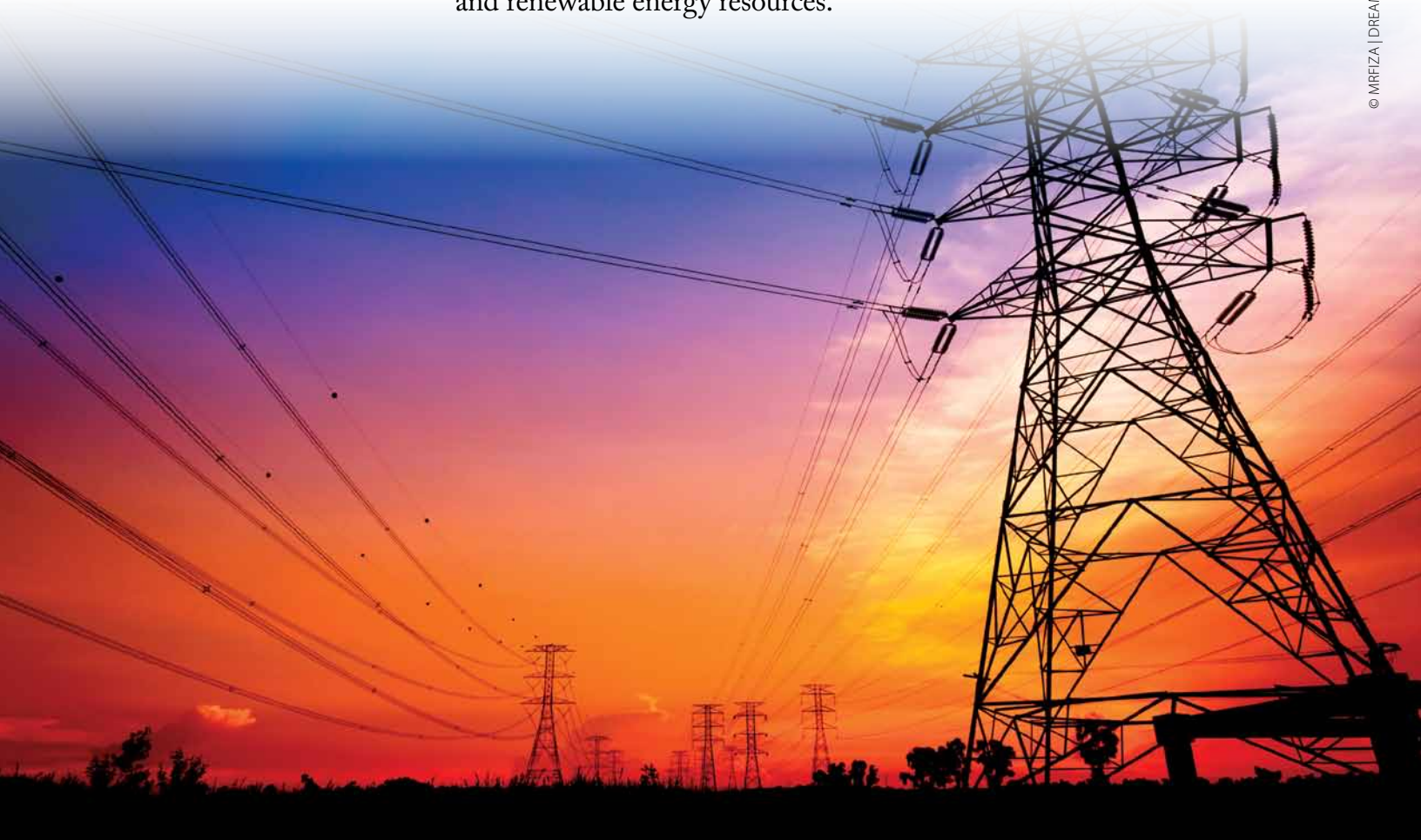
Reading 2

Energy Today

The world uses more energy today than ever before, thanks to population growth, increasing transportation of people and products around the world due to globalization, and technology-rich lifestyles that require a constant supply of energy. While oil remains the world's leading fuel, there are many other energy resources used around the globe. Are there limits to the amount of energy available to us? How do different energy sources compare? And how do we determine which energy sources are most sustainable?

The answers to these questions are central to finding a way for all people to use energy sustainably. When evaluating different energy sources, we must look closely at the economic, environmental, and social consequences of using each source of energy. In the following section, you can learn about the main pros and cons of different nonrenewable and renewable energy resources.



Nonrenewables

Nonrenewable energy resources are limited and cannot be replaced in a short amount of time. They include oil, natural gas, coal, and uranium.

Oil

The energy resource that the world uses more than any other is petroleum, or oil.[1] You probably know that oil is primarily used for transportation: it can be refined (processed) to produce diesel, gasoline, and even jet fuel. But did you also know that oil is an ingredient in many of the products we use? Medicines, shampoos, make-up, tires, and plastics can all be made from petroleum. So can clothes that are made with nylon, rayon, or polyester.[2]

Oil is a fossil fuel that is usually found deep within Earth. It is extracted by drilling down into Earth and pumping it up to the surface. Oil is not readily found everywhere around the globe, which is why many countries import oil from other countries. The largest **oil reserves** are found in Saudi Arabia and Venezuela.[3]

As with other nonrenewable resources, there is a limited supply of oil. This can increase competition for this resource and has historically led to international conflict. Countries that import a large portion of their oil have less control over the price and supply of this resource than they would over a domestic resource.

In addition, throughout most of its life cycle—from exploration and extraction to consumer use—oil is linked to pollution. The process of searching for and extracting oil is unpredictable and can impact the health of the surrounding environment. Transporting oil itself requires fuel and creates the potential for oil leaks or spills. Burning oil products in a car, jet, or power plant produces large amounts of pollution that can affect the health of humans, animals, and ecosystems.

On the other hand, one main benefit of using oil is that it is energy dense. **Energy density** describes the amount of energy stored in a given volume or space. In fact, oil is more energy dense than natural gas, coal, and biomass. Also, much of the infrastructure needed to refine and distribute oil is already in place. For example, pipelines, roads, gas stations, and most car engines are manufactured to support oil use. Because oil is a form of chemical energy, it can be stored until it is needed and since oil is a liquid, it is easier to transport than coal.

Oil is a fossil fuel that can be extracted from underground reservoirs.

As sources of easily accessible oil are depleted, it will take more and more energy (and money) to extract oil from places that are harder to reach. As it becomes less lucrative to extract fossil fuels like oil, the rate of oil production may eventually begin to decline. Many people refer to this situation as peak oil.[4]

Natural Gas

Natural gas is another fossil fuel found in many places around the world. The largest natural gas reserves in the world are found in Russia.[5] Natural gas is mostly used as a heat source and as an ingredient in products like fertilizers, plastics, glue, and paint.[6] Although natural gas does emit some pollution when burned, it produces about half the carbon dioxide of coal and is the cleanest fossil fuel to burn.[7]

oil reserves—The estimated amount of oil that is currently available and recoverable with existing equipment and under existing conditions.

energy density—The amount of energy stored in a given volume or space.

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Natural gas is often transported through pipelines.

Natural gas has traditionally been extracted from underground reservoirs in porous rock by drilling vertical wells that average about 6,100 feet deep.[8] Once found, natural gas is usually transported from one location to another via underground pipelines. More than 300,000 miles of underground pipeline transport natural gas throughout the United States.[9] The pipelines are relatively cheap to maintain (though expensive to build) and many are already in place.[10]

Recent advances in technology have helped engineers capture natural gas that is trapped in shale formations (fine-grained sedimentary rock). Horizontal drilling and hydraulic fracturing, or fracking, are two techniques engineers use to obtain hard-to-reach natural gas. During hydraulic fracturing, water, sand, and chemicals are injected into underground wells to create cracks in the rock. This process forces natural gas up to the surface.[11] Horizontal drilling allows gas to be recovered parallel to rock layers rather than drilling deeper.

Horizontal drilling and hydraulic fracturing make it possible to extract more natural gas from each well. However, fracking uses a large amount of water and produces large amounts of wastewater. If wells are not properly installed, it also has the potential to leak chemicals into nearby water sources and ecosystems. Fracking may lead to land instability and in rare instances may even cause small earthquakes.[12]

Coal

A third type of fossil fuel is **coal**. Although it is less energy dense than oil or natural gas, it can still provide a good amount of energy. Coal is a relatively abundant and inexpensive energy source. In fact, the use of coal is expected to increase in future years, especially in developing countries.[13] Together the United States, Russia, and China have about 60% of the world's coal reserves.[14]

Most of the coal used in the United States is burned to produce electricity. Coal is also used to manufacture products such as steel, paper, and cement. Coal mining and the manufacturing that results from coal can encourage economic development by creating jobs in these sectors. For the many countries that mine it domestically, coal can be more economically and politically secure than oil.

Coal is extracted from the earth by either surface mining or underground mining. Surface (or strip) mining removes the land above coal deposits.[15] Sometimes explosives are even used to remove land above coal; this is called mountain top removal. The blasted earth often ends up in valleys or in waterways, which damages ecosystems, wildlife, and water quality. There have been some legislative attempts to control the pollution that results from this type of surface mining, but these laws have not always been successful.[16] Federal law requires mining companies to return blasted mountaintops to their original shape, but this does not often happen.[17]

In underground mining, equipment and workers go hundreds of feet below ground to extract coal. People who mine coal are exposed to many dangers: the ground above them can collapse and exposure to years of coal dust can cause health problems such as black lung disease.

Coal generates the most pollution of all fossil fuels. The extraction and combustion of coal releases many substances that can affect human health, damage the environment, and contribute to climate change. Burning coal is the leading cause of both sulfur and mercury pollution, which is harmful for humans and ecosystems.[18] Other byproducts of coal can contribute to poor air quality and respiratory problems. Coal mines

can release methane (a greenhouse gas) into the atmosphere and, once abandoned, can leak acidic water into the environment.[19] In order to reduce the amount of pollution emitted into the atmosphere, scientists are working to develop technology to capture pollution before it leaves the power plant.[20]

SOUTHWINGS

Mountaintop removal mining involves using explosives to remove land above coal deposits.

Nuclear

Nuclear energy refers to the energy stored within the nucleus of an atom. When atoms are split, a large amount of heat is released. This amount of energy is so great that it can heat water up to 520° Fahrenheit![21] Steam from this hot water can be used to turn turbines to generate electricity.

The primary fuel used for nuclear energy is uranium—a nonrenewable resource. Uranium can be found in rocks and extracted from surface or underground mines. Uranium can also be recovered from oceans. Once extracted, uranium is then processed into fuel for nuclear power plants that convert it into electricity. About 13.5% of the world's electricity is generated from nuclear energy and about 30 countries operate nuclear power plants.[22]

One main drawback of nuclear energy is the radiation given off by the process of nuclear fission and the nuclear waste generated by nuclear power plants. This waste will remain radioactive for thousands of years. There is no permanent disposal site for the highly radioactive waste in the United States and most of it is stored at nuclear power plants.[23] Radioactive materials are hazardous to human health. For example, four years after a 1986 nuclear accident at the Chernobyl nuclear power plant in Ukraine, the World Health Organization reported 5,000 cases of thyroid cancer in children ages 18 and younger.[24] Because radioactive materials are hazardous to human health, many

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The hot steam generated during nuclear fission is cooled using cooling towers.

people do not want a nuclear reactor or waste near their homes.

Another drawback to nuclear energy is that a lot of water is used to cool down the steam produced to generate electricity. This water can come from nearby lakes, rivers, or oceans. Due to the serious nature of the risks to the nearby environment and human health, nuclear power plants have many safety systems created to prevent accidents. The failure of these systems can be tragic. For example, in the wake of a 2011 earthquake and tsunami off the coast of Japan, the Fukushima nuclear power plant lost power. A couple small fires started and radioactive waste was released.[25] Due to the risk of radiation, over 100,000 people were evacuated from their homes.[26]

Despite the above concerns, there are many reasons why countries might turn to nuclear power as a source of electricity. Uranium has an incredibly high energy density; one ceramic pellet of uranium is about as big as your fingertip yet has about as much energy as 150 gallons of oil.[27] Although energy (usually from fossil fuels) is required to mine and refine uranium, nuclear fission is a way to produce electricity without creating greenhouse gases and other air pollutants.

Hydroelectric dams convert the kinetic energy of moving water into electricity.

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Renewables

Renewable energy resources are able to be replaced quickly and naturally. They include moving water, biomass, heat from Earth's core, and the sun.

Water

Have you ever river rafted or been caught in a rip tide just off the beach? If so, you know that water is powerful. Fast-flowing water, waterfalls, ocean tides, and waves all contain kinetic energy that can be harnessed to generate electricity. Fast-flowing water, waterfalls, ocean tides, and waves all contain kinetic energy that can be harnessed to generate electricity. Water (or hydroelectric) power refers to the kinetic energy of moving water. Because water is renewed naturally through the earth's water cycle, water power is considered a renewable energy source.

Most electricity generated from water relies on moving water to turn turbines that capture the water's kinetic energy. This can look different depending on the location and source of water. For example, tidal fences are vertical structures built in the oceans that are embedded with turbines. As the tides move in and out, the flowing water turns the turbines.[28] Hydroelectric power plants, on the other hand, are constructed near freshwater dams. Gates open to release water stored behind the dam so that water flows through turbines to generate electricity.[29]

Producing electricity from moving water does not result in significant carbon dioxide emissions or air pollution because no fuel is burned. However, hydroelectric power may result in some emissions from water reservoirs (bodies of water held by dams). Water is denser than air, so a turbine built for tides can capture more energy than wind. However, this can make the turbine more costly to build because it must be sturdy.[30]

Many countries around the world have built dams in order to generate hydroelectric power. China produces the most hydroelectricity in the world and has created the largest

hydroelectric dam in existence.[31] The Three Gorges Dam was built on China's Yangtze River and produces about 85 Terawatthours (TWh) per year. Eighty-five TWh will meet a tenth of China's current annual electricity need.[32] Hydroelectric power plants provide some of the least expensive electricity to consumers and are about 90% efficient in converting the water's kinetic energy into electricity.[33]

However, building large dams can have high monetary, ecological, and social costs. Often people who live in the area must move to allow the flooding of land to create a reservoir. It is estimated that over 1.4 million people were displaced from their homes by the construction of the Three Gorges Dam.[34] In addition, sediments (soil, sand, and leaves) can build up in reservoirs, decay, and produce methane emissions.[35] That sediment reduces water quality for organisms that live in the water and can choke out the sun's light. Changing the path of a waterway affects any organisms dependent on that waterway. Migrating fish, such as salmon, may have trouble swimming around dams. Damming may also cause erosion along riverbanks.

In response to these ecological concerns, there have been some efforts to remove dams and restore rivers and their surrounding ecosystems to their natural state. For instance, the Elwha Dam in Washington State was removed in 2012 to help restore the river and fisheries.[36] There is also interest in creating smaller, low-cost hydropower technology that would cause less damage to the environment while still producing energy from a renewable resource.[37]

Biomass

Biomass, or bioenergy, is recently living organic material that can be used as a fuel source. In the process of photosynthesis, plants and organisms like algae capture sunlight and convert it to chemical energy. Humans have used wood (one type of biomass) for years to provide heat for their homes and cook their food. More recently, people have begun burning biomass to generate electricity as well as converting biomass into liquid fuels to run cars and trucks. Wood is still the most common form of biomass used today, but animal dung (waste), grasses, algae, corn, sugarcane, and even garbage or wood waste from construction can be used as fuel.[38]

TANZANIA/© 2003 SARAH BONES/CARE

Wood is the most common form of biomass used today.

Biomass is considered a renewable energy source because organic matter can be regrown relatively quickly. To accurately evaluate the sustainability of biomass, one would need to take a close look at each type of biomass and the way that it is harvested and grown.

Like fossil fuels, burning biomass directly or as transportation fuel produces carbon dioxide emissions. Unlike fossil fuels, the carbon dioxide released by burning biomass was recently absorbed from the atmosphere as part of the natural carbon cycle. If biomass is regrown, it can absorb carbon dioxide from the atmosphere and release oxygen. By contrast, burning fossil fuels releases carbon dioxide that has not been in the atmosphere for millions of years. However, if biomass is not replanted at the same rate that it is being used, the result could be increased carbon dioxide emissions and deforestation.

There are other downsides to biomass energy. Fertilizers and chemical pesticides that might be used to grow biomass are made from fossil fuels. Also, converting land once used to produce food into land that produces biomass for fuel can have negative global impacts on food supply and prices that would likely affect the people in our world that most need food.

YOUTH PROFILE

Whitney M. Young Magnet High School

Sophomore Anna Hernandez wanted to learn more about alternative and green energy technology for a science fair project. She found out about something called biodiesel, a type of fuel made by combining oil with ethanol or methanol. When used in farm machinery or other diesel engines, biodiesel produces fewer greenhouse gases than petroleum-based diesel.

With help from the University of Illinois at Chicago and teacher Brian Sievers, Anna Hernandez and four other students from Chicago's Whitney M. Young Magnet High School created a functional, full-sized biodiesel production system. They converted 1,460 gallons of cooking oil from neighborhood restaurants into biodiesel fuel. They donated biodiesel to farmers and others who use diesel engines.[39]

The students then built and donated a biodiesel system to Mendota High School, a school in rural Illinois, so they could share with the students there what they learned. "They were totally excited to get started making biodiesel," said Sabrina Kwan, a sophomore at Whitney Young. The project even crossed national borders when the students gave a presentation on how to make a biodiesel system to a company in Honduras!

Wind

Wind is produced because the sun heats the surface of the earth unevenly, causing air to circulate. This moving air is a renewable form of energy that can be converted into electricity. When wind turns the blades of a wind turbine, a generator inside the gearbox (at the top of the tower) converts the mechanical action into electricity. Cables inside the tower transmit this energy to a transformer where it is converted to a voltage appropriate for transmission to your home.[40]

The use of wind energy to produce electricity is increasing around the world.[41]

PHOTO COURTESY OF JORDAN STALKER

Whitney M. Young students converted used cooking oil into biodiesel.

The main benefit of using wind power is that once a wind farm is set up, it does not produce air or water pollution. There is also no need to buy fuel; wind is free. However, wind is an intermittent energy source. The wind does not always blow when people want electricity and the speed of wind cannot be controlled, reducing the reliability of electricity produced by wind.

With new smart grid technologies, however, this problem could be mitigated. An **electric grid** is made up of all of the equipment (i.e., transmission lines, transformers) necessary to transfer electricity from a power plant to a customer. A smart grid refers to an electric grid that has technology to allow the two-way communication of information about electricity production and consumption to flow between producers to consumers. This information can be used to increase the efficiency of our electricity system by helping consumers maximize their use of wind energy.[42] For example, smart grids used in the country of Denmark help citizens know when there is enough wind energy available to use appliances in their homes.[43]

Wind is not a universally popular source of energy. Wind turbines require large amounts of land and there may be competing interests for the use of this land, such as farming or cattle. Wind farm opponents claim that wind turbines ruin the landscape and cause noise pollution. Wind turbines can kill migrating birds and careful placement is needed to reduce this effect.

Offshore wind farms, or wind turbines located in bodies of water, are also gaining popularity around the world. While the United States has been slow to adopt wind turbines in oceans, there are 12 countries that have (90% of these are in Europe[44]). Opponents to offshore wind turbines in the United States are concerned about the view of the turbines from the shore. Yet according to the Earth Policy Institute, "Nine of the top 10 carbon dioxide emitting countries in 2010 have more than enough offshore wind energy potential to meet all their current electricity needs."[45]

NUALABUGEYE

The use of wind energy to produce electricity is increasing around the world.

Geothermal

One renewable form of energy that is not derived from the sun is geothermal energy. Geothermal energy comes from heat produced in the earth's core. This energy can be used to provide heat or generate electricity from steam produced by this heat. At least one quarter of electricity in the Philippines, Iceland, and El Salvador comes from geothermal energy.[46]

Earth contains an incredible amount of geothermal energy. The amount of heat that flows from the earth into the atmosphere each year is equal to 10 times the amount of energy that the United States uses each year.[47] This type of energy produces very few emissions (1-3% of the carbon dioxide and 3% of the acid rain produced by fossil fuels).[48]

electric grid—A system that distributes electricity from power plants to locations that use electricity; it includes power lines, power generators, transformers, and all of the homes and businesses that use electricity.

However, some pollution such as hydrogen sulfide (which can contribute to acid rain and smells like rotten eggs) can naturally occur in water heated by geothermal energy. Also, geothermal energy is not located everywhere and the cost of exploratory drilling and the initial setup of power plants can be high. Corrosion can also be a problem with geothermal energy.[49]

CASE STUDY Barefoot Solar Engineers[50]

Envision a college where young people, parents, and even grandparents—most of whom cannot read or write—are admitted to train to become solar engineers, water specialists, dentists, doctors, teachers, mechanics, architects, artisans, masons, computer programmers, and accountants.

This is a college that welcomes people who are often seen as "uneducated" and "useless" by society who can indeed learn to build and install solar lighting or manage the primary health care and basic education of thousands of poor children and hundreds of villages across rural India, Africa, Asia, and South America. This place is Barefoot College in the village of Tilonia, in Rajasthan, India.

KIMBERLY CORRIGAN

Barefoot College trains people from impoverished rural areas to bring sustainable solutions such as solar electrification to their communities.

Barefoot College is a non governmental organization founded in 1972. Its purpose is to help impoverished rural communities become self-sufficient and sustainable. It seeks to halt the mass migration of unemployed people to overcrowded cities and urban slums, retaining them in their villages with meaningful work. Because the organization believes that successful development must be rooted and managed by the community, their approach is to listen to what communities need and then train through apprenticeship so that people return to their communities prepared to thrive and help others do the same.

The Barefoot College asserts—as did the world-renowned Indian leader of nonviolent civil disobedience Mahatma Gandhi—that the skills and wisdom of rural communities should be honored and used to foster lasting change, and that technology should be managed by the locals to prevent the community from becoming exploited or dependent on outside help. The college stresses the importance of demystifying new technologies and decentralizing their use, as well as promoting traditional knowledge and skills that have been employed successfully for millennia. Let's look at one example—bringing solar power to nonelectrified, rural villages.

The process begins with an interested community forming a Village Environmental Energy Committee. This committee communicates with villagers about solar power and will collect a small monthly payment from families participating in the subsidized program. The committee and community select individuals to attend a six-month, in-residence training program at Barefoot College's campus. The college often encourages communities to pick people who struggle to find employment such as single mothers or widows. Upon completion the "Barefoot Solar Engineers" return home, manage the project, and earn a monthly stipend.

At the Barefoot College the message is clear: being educated is about more than reading and writing, it's about caring for yourself, your community, and the world around you.

Geothermal energy comes from the heat produced in Earth's core.

Solar

Solar energy comes directly from the earth's star, the sun. This energy can be harnessed passively or actively to heat homes and water or to generate electricity. For years, humans have been building homes and shelters to take advantage of the sun. For example, ancient Roman bathhouses were built facing south toward the sun. In the 1200s, the Anasazi people in North America sheltered themselves in south-facing cliff shelters in order to warm their environments.[51] Many homes today are still built to capture winter sun and deflect summer sun.

Like wind and water, sunlight is free and solar energy is a renewable resource. Photovoltaic cells, or solar cells, allow us to actively capture sunlight and convert it to electricity. Solar cells can be installed on people's homes to provide direct electricity for their needs. Any extra solar energy can be sent back to the city's electrical grid.

Manufacturing photovoltaic cells, however, requires energy, the extraction of resources, and the use of toxic chemicals that must be disposed of properly. Currently, solar cells are fairly inefficient and convert only about 11-27% of the sun's energy into electricity.[52]

Solar energy is also a diffuse form of energy and concentrating and storing it can be challenging.[53] Like wind, sunlight is not consistent or steady. Time of day, season, latitude, and cloudiness all impact the amount of solar energy available.[54] For example, a desert location can get over six kilowatt-hours per day per square meter, while a cloudy December day in Seattle can receive as little as 0.7 kilowatt-hours per day.[55]

CHECK FOR UNDERSTANDING

1. In general, what are some of the benefits and trade-offs of using nonrenewable energy sources? What are some of the benefits and trade-offs of using renewable energy sources?
2. How might geography or location affect the sustainability of a particular energy source?
3. How could a nation benefit from using a diversity of energy resources? Might there be any disadvantages to having a diverse fuel mix?