Section 1: Sources of Energy

Types of Energy[1]

All the things we use every day to meet our needs and wants are provided through the use of natural resources. Natural resources are either renewable or nonrenewable.

Renewable resources are materials that can be replaced through natural and/or human processes.

Nonrenewable resources exist in fixed amounts within Earth and once they're used up, they are gone forever or it takes the planet an extreme amount of time to make them.

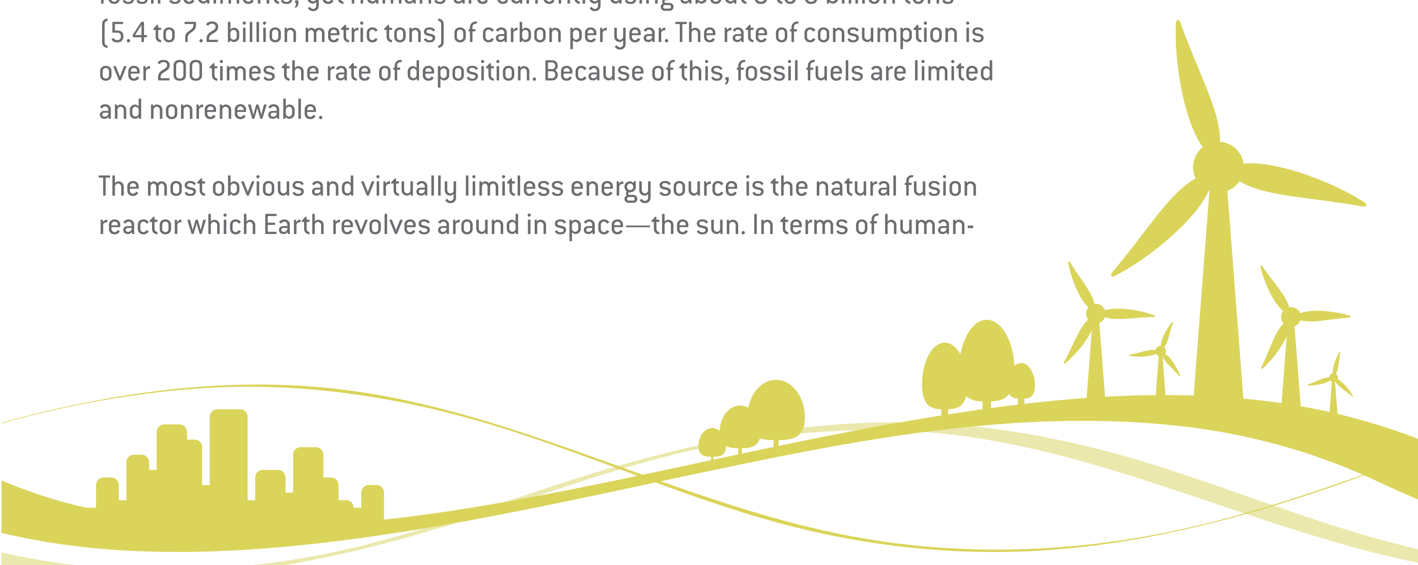
Energy is derived from natural resources. We use energy to light, heat, and cool our homes, offices, and factories. Energy powers the machines of industry and transportation. We depend on energy to help us manufacture the clothing we wear, the food we eat, the buildings in which we live and work, and even the systems we use to communicate.

For generations, our society has been enjoying the benefits of plentiful, inexpensive, and easily available energy—fossil fuels. But these fuels, such as coal, oil, and natural gas, are finite. As supplies have decreased and become more expensive to extract, the search has intensified for alternative energy sources (i.e., sources of energy other than fossil fuels).

Past studies and evidence suggest that every year about 28 to 30 million tons (25.4 to 27.2 million metric tons) of carbon go into the formation of new fossil sediments, yet humans are currently using about 6 to 8 billion tons (5.4 to 7.2 billion metric tons) of carbon per year. The rate of consumption is over 200 times the rate of deposition. Because of this, fossil fuels are limited and nonrenewable.

The most obvious and virtually limitless energy source is the natural fusion reactor which Earth revolves around in space—the sun. In terms of human-

SECTION 1: Activities



kind's residence on Earth, the sun is an object that will last forever. It continuously radiates energy that makes life on our planet possible. Although Earth intercepts only a small fraction of the total energy emitted by the sun, the amount received is thousands of times the present energy requirement of the world's human population.

Other renewable energy sources include wind energy, hydroelectric energy, biomass energy, geothermal energy, and various forms of energy derived from the ocean. New ways and ideas to harness or use these renewable energy sources are continually being researched and developed.

The Development of Photovoltaics[2]

Photovoltaic (PV) systems are solar-energy systems that generate electricity directly from sunlight. Photovoltaic systems produce clean, reliable energy without consuming fossil fuels and without any moving parts. They can be used in a wide variety of applications. A common application of PV technology is providing power for watches and radios. On a larger scale, many utilities have recently installed large PV arrays to provide consumers with solar-generated electricity or as backup systems for critical equipment.

Research into PV technology began over 100 years ago. In 1873, British scientist Willoughby Smith noticed that selenium was sensitive to light. Smith concluded that selenium's ability to conduct electricity increased in direct proportion to the degree of its exposure to light. This observation of the photovoltaic effect led many scientists to experiment with this relatively uncommon element with the hope of using the material to create electricity. In 1880, Charles Fritts developed the first selenium-based solar-electric cell. The cell produced electricity without consuming any material substance and without generating heat.

In the early 1950s, Bell Laboratories and RCA laboratories began a search for a dependable way to power remote communication equipment. Bell scientists discovered that silicon, the second most abundant element on Earth, was sensitive to light and, when treated with certain impurities, generated a substantial voltage. By 1954, Bell developed a silicon-based solar cell that achieved 6% efficiency. The total solar resource available is 1,000 watts per square meter, thus the first solar panel was able to produce 60 watts.

Solar Electricity[3]

Solar cells, also called PV cells, are made of semiconducting materials similar to those used in computer chips. When sunlight is absorbed by these materials, the solar energy knocks electrons loose from their atoms, allowing the electrons to flow through the material to produce electricity. This process of converting light (photons) to electricity (voltage) is called the PV effect.

Solar cells are typically combined into modules that hold about 40 cells. About 10 of these modules are mounted in PV arrays that can measure up to several meters on a side. These flat-plate PV arrays can be mounted at a fixed angle facing south, or they can be mounted on a tracking device that follows the sun, allowing them to capture the most sunlight over the course of a day. About 10 to 20 PV arrays can provide enough power for a household. For large electric utility or industrial applications, hundreds of arrays can be interconnected to form a single, large solar-electric system.

Thin-film solar cells use layers of semiconductor materials only a few micrometers thick. Thin-film technology has made it possible for solar cells to double as rooftop shingles, roof tiles, building facades, or the glazing for skylights or atria. The solar-cell version of items such as shingles offer the same protection and durability as ordinary asphalt shingles.

Some solar cells are designed to operate with concentrated sunlight. These cells are built into concentrating collectors that use a lens to focus the sunlight onto the cells. This approach has advantages and disadvantages compared with flat-plate PV arrays. The main idea is to use very little of the expensive semiconducting PV material while collecting as much sunlight as possible. But because the lenses must be pointed at the sun, the use of concentrating collectors is limited to the sunniest parts of the world. Some concentrating collectors are designed to be mounted on simple tracking devices but most require sophisticated tracking devices, which further limit their use to electric utilities, industries, and large buildings.

The performance of a solar cell is measured in terms of its efficiency at turning sunlight into electricity. Only sunlight of certain intensities will work efficiently to create electricity, and most of the sunlight is reflected or absorbed by the materials that make up the cell. Because of this, a typical commercial solar cell has an efficiency of 15%, which means that only about 15% of the sunlight striking the cell generates electricity. Photovoltaic arrays are large and expensive because of the low efficiency of solar cells. Improving solar cell efficiencies while holding down the cost per cell is an important goal of the PV industry. The industry has already come a long way. In the 1950s, the first solar cells had efficiencies of less than 4%.

Passive Solar[4]

Step outside on a hot and sunny summer day, and you'll feel the power of solar heat and light. Today many buildings are designed to take advantage of this natural resource through the use of passive solar heating and daylighting.

The south side of a building always receives the most sunlight. Therefore, buildings designed for passive solar heating usually have large, south-facing windows. Materials that absorb and store the sun's heat can be built into the sunlit floors and walls. The floors and walls will then heat up during the day and slowly release heat at night, when the heat is needed most. This passive solar design feature is called direct gain. Other passive solar heating design features include sunspaces and trombe walls. A sunspace (which is much like a greenhouse) is built on the south side of a building. As sunlight passes through glass or other glazing, it warms the sunspace. Proper ventilation allows the heat to circulate into the building. Another passive solar feature is a trombe wall, which is a thick, south-facing wall that is painted black and made of a material that absorbs a lot of heat. A pane of glass or plastic glazing, installed a few inches in front of the wall, helps hold in the heat. The wall heats up slowly during the day. Then as it cools gradually during the night, it gives off its heat inside the building.

Many of the passive solar heating design features also provide daylighting, which is simply the use of natural sunlight to brighten up a building's interior. To lighten up north-facing rooms and upper levels, a clerestory—a row of windows near the peak of the roof—is often used along with an open floor plan inside that allows the light to bounce throughout the building.

Of course, too much solar heating and day lighting can be a problem during the hot summer months. Fortunately, there are many design features that help keep passive solar buildings cool in the summer. For instance, overhangs can be designed to shade windows when the sun is high in the summer. Sunspaces can be closed off from the rest of the building. And a building can be designed to use fresh-air ventilation in the summer.

Advantages and Disadvantages of Solar Energy

Advantages of Solar[5]

- Photovoltaic (PV) technology is highly reliable and needs little maintenance. Many panels are warranted 20 years or more.
- Photovoltaic technology costs little to build and operate. As it costs increasingly less to produce and use, PV becomes more affordable and available.
- Few power-generation technologies have as little impact on the environment as solar energy. As it quietly generates electricity from light, PV produces no air pollution or hazardous waste. It doesn't require liquid or gaseous fuels to be transported or combusted. And because its energy source (sunlight) is free and abundant, solar-electric systems can guarantee access to electric power.
- Photovoltaic technology is produced domestically, which helps strengthen the U.S. economy and reduce our trade deficit.
- As a domestic source of electricity, solar contributes to the nation's energy security.
- As a relatively young, high-tech industry, the solar industry helps to create jobs and strengthen the economy.
- Photovoltaics are modular and thus flexible in terms of size and applications.
- Solar energy helps meet the demand and capacity challenges facing energy service providers.

Disadvantages of Solar

- Currently, there is a limited supply of materials to produce solar modules. This limited supply keeps the price of PV high.
- There is limited manufacturing of PV in relation to the growing demand for the technology.
- There are limited tax credits and incentives available to help offset the high cost of PV.
- Wide-spread use of solar power requires a shift in the fundamental structure of the U.S. energy supply.

Development of Wind Energy[6]

Since early recorded history, people have been harnessing the energy of the wind. Wind energy propelled boats along the Nile River as early as 5000 B.C. By 200 B.C., simple windmills in China were pumping water, while vertical-axis windmills with woven reed sails were grinding grain in Persia and the Middle East.

New ways of using the energy of the wind eventually spread around the world. By the 11th century, people in the Middle East were using windmills extensively for food production; returning merchants and crusaders carried this idea back to Europe. The Dutch refined the windmill and adapted it for draining lakes and marshes in the Rhine River Delta. When settlers took this technology to the New World in the late 19th century, they began using windmills to pump water for farms and ranches, and later, to generate electricity for homes and industry.

Industrialization, first in Europe and later in America, led to a gradual decline in the use of windmills. The steam engine replaced European water-pumping windmills. In the 1930s, the Rural Electrification Administration's programs brought inexpensive electric power to most rural areas in the United States.

However, industrialization also sparked the development of larger windmills to generate electricity. Commonly called wind turbines, these machines appeared in Denmark as early as 1890. In the 1940s the largest wind turbine of the time began operating on a Vermont hilltop known as Grandpa's Knob. This turbine, rated at 1.25 megawatts in winds of about 30 mph, fed electric power to the local utility network for several months during World War II.

The popularity of using the energy in the wind has always fluctuated with the price of fossil fuels. When fuel prices fell after World War II, interest in wind turbines waned. But when the price of oil skyrocketed in the 1970s, so did worldwide interest in wind turbine generators.

Research and development into wind turbine technology that followed the oil embargoes of the 1970s refined old ideas and introduced new ways of converting wind energy into useful power. Many of these approaches have been demonstrated in "wind farms" or wind power plants (i.e., groups of turbines that feed electricity into the utility grid) in the United States and Europe.

Today the lessons learned from more than a decade of operating wind power plants, along with continuing research and development, have made wind-generated electricity very close in cost to the power from conventional utility generation in some locations. Wind energy is the world's fastest-growing energy source and will power industry, businesses, and homes with clean, renewable electricity for many years to come.

Wind as Energy[7]

Wind is a form of kinetic energy created in part by the sun. About 2% of the sun's energy that reaches Earth is converted to wind energy. The atmosphere is heated during the day by the sun, and at night it cools by losing its heat to space. Wind is the reaction of the atmosphere to the heating and cooling cycles, as well as Earth's rotation. Heat causes low pressure areas, and the cool of the night results in high pressure areas. This process creates wind as air flows from high pressure areas into low pressure areas. Wind flow patterns are modified by Earth's terrain, bodies of water, and vegetation. Humans use this wind flow, or motion energy, for many purposes such as sailing, flying a kite, and even generating electricity.

So how do wind turbines make electricity? Simply stated, a wind turbine works the opposite of a fan. Instead of using electricity to make wind, like a fan, wind turbines use wind to make electricity. The wind turns the blades, which spin a shaft, which connects to a generator and makes electricity.

Wind energy offers many advantages, which explains why it is one of the fastest-growing energy sources in the world. Research efforts are aimed at addressing the challenges to greater use of wind energy.

Advantages and Disadvantages of Wind Energy[8]

Advantages of Wind Energy

- Wind energy is fueled by the wind, so it's a clean fuel source. Wind energy doesn't pollute the air like power plants that rely on combustion of fossil fuels, such as coal or natural gas. Wind turbines don't produce atmospheric emissions that cause acid rain or greenhouse gasses.
- Wind energy is a domestic source of energy, produced in the United States. The nation's wind supply is abundant.
- Wind energy relies on the renewable power of the wind, which can't be used up.
- Wind energy is one of the lowest-priced renewable energy technologies available today, costing between four and six cents per kilowatt-hour, depending upon the wind resource and project financing of the particular project.
- Wind turbines can be built on farms or ranches, thus benefiting the economy in rural areas, where most of the best wind sites are found. Farmers and ranchers can continue to work the land because the wind turbines use only a fraction of the land. Wind power-plant owners make rent payments to the farmer or rancher for the use of the land.

Disadvantages of Wind Energy

- Wind power must compete with conventional generation sources on a cost basis. Depending on how energetic a wind site is, the wind farm may or may not be cost competitive. Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment than fossil-fueled generators.
- The major challenge to using wind as a source of power is that the wind is intermittent and it does not always blow when electricity is needed. Wind energy cannot be stored (unless batteries are used), and not all winds can be harnessed to meet the timing of electricity demands.
- Good wind sites are often located in remote locations, far from cities where the electricity is needed.
- Wind resource development may compete with other uses for the land, and those alternative uses may be more highly valued than electricity generation.
- Although wind power plants have relatively little impact on the environment compared to other conventional power plants, there is some concern over the noise produced by the rotor blades, aesthetic (visual) impacts, and the impact on wildlife (such as birds and bats) that are sometimes killed by wind rotors. Most of these problems can be resolved or greatly reduced through technological development or by properly situating wind plants.

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1 Text for *Types of Energy* was adopted from the National Energy Foundation.

2 Text for *The Development of Photovoltaics* was adopted from the Solar Radiation Monitoring Lab.

3 Text for *Solar Electricity* was adopted from National Renewable Energy Laboratory.

4 Text for *Passive Solar* was adopted from the National Renewable Energy Laboratory.

5 Text for *Advantages of Solar* was adopted from the Department of Energy.

6 Text for *Development of Wind Energy* was adapted from the Department of Energy.

7 Text for *Wind Energy* was adapted from National Energy Foundation.

8 Text from *Advantages and Disadvantages* of Wind Energy was adapted from the Department of Energy.