ALTERNATE ENERGY SOURCES

What are the Facts ?

The Texas Institute for
Advancement of Chemical Technology
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ALTERNATE ENERGY SOURCES

INTRODUCTION

This FLYER is an abbreviated summary of INSIGHTS - *Alternate Energy Sources*. There follows a presentation in the form of Questions and Answers on alternate energy sources. More attention is given to nuclear than to the other alternate energy sources because of its importance. Nuclear energy is second only to coal in the production of electricity, and it has the greatest potential for replacing coal as the major energy source for the production of electricity.

Q **What are two of the major energy problems facing the United States today and what is the key to their solution?**

A The two major energy problems facing the United States are:

- Reduction of greenhouse gases and other pollutants.
- Reduction of the dependence of the United States on foreign oil.

The key to the solution of these problems makes use of ***alternate energy sources***. The first of these problems may be solved by replacing fossil fuels in the generation of electricity by one or more of the alternate energy sources. The best solution (or solutions) to the second problem is not clearly evident at the present time except for the fact that electrical energy generated from alternate energy sources has a significant role to play. Furthermore, the alternative to foreign oil must be a secure energy source - one not subject to being cut off, as could occur with the Middle Eastern oil supply. The technologies for the utilization of alternate energy sources to reduce our dependence on foreign oil are still under development. A discussion of these technologies are outside the scope of this report.

Q **What is the relationship between Electricity Sales, Gross Domestic Product, and Population?**

A Increases in Gross Domestic Product, Population, and Electricity Sales go hand-in-hand as demonstrated in Figure 1. An increasing population will increase the demand for the necessities of life as evidenced by the increase in Electricity Sales and Gross Domestic Product.[1]

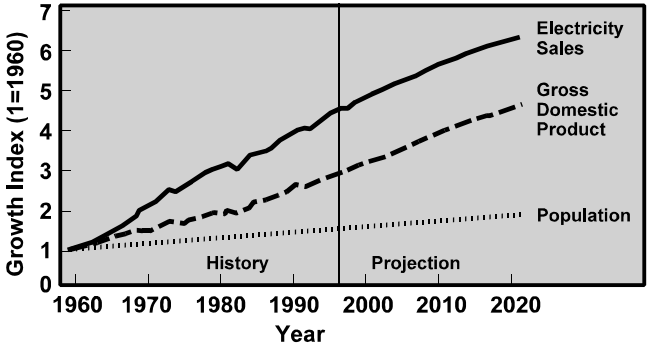

Figure 1. As Population Increases So Does Gross Domestic Product and Electricity Sales.[1]

Q **How is the use of the fossil fuels, petroleum, natural gas, and coal expected to increase?**

A Use of these major fossil fuels is expected to increase in the 21st century as shown in Figure 2. As a result of the projected increase in population, an increase in petroleum is projected for the production of gasoline and the chemical products that have become necessities in our way of life. Both natural gas and coal are projected to increase in the production of electricity. Natural gas is projected to increase faster than coal for the generation of electricity because it is an environmentally cleaner fuel than coal.[2]

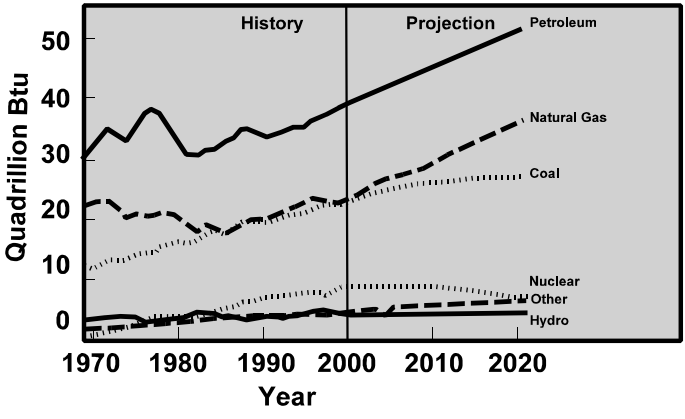

Figure 2. Use of the Fossil Fuels in the Production of Gasoline, Diesel, and Electricity.[2]

Q **What are the major alternate energy sources?**

A The major alternate energy sources in the order of their importance are as follows:

- **Nuclear**
- **Hydropower**
- **Geothermal**
- **Biomass**
- **Wind**
- **Solar**

Q **What is the present distribution of energy sources in the production of electricity?**

A As shown in Figure 3, 56.2% of all electricity is produced from coal, 21% from nuclear energy, 9.6% from natural gas, 9.5% from hydropower, 3.4% from petroleum, and 0.2% from other sources (geothermal, biomass, wind, and solar).[3]

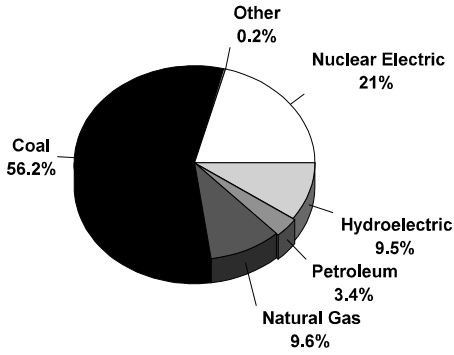

Figure 3. Production of Electricity in the United States in 1999
(Source: Energy Information Center[3])

Q **What are the renewable energy sources and what are their respective contributions in the United States?**

A The category of ***renewable energy sources*** includes all alternate energy sources except nuclear; namely, hydropower, geothermal, biomass, wind, and solar. Of the electricity produced by use of renewable energy sources, hydropower is the largest at 97.7% followed by geothermal at 1.67%, biomass at 0.6%, wind at 0.001% and solar at 0.001% as shown in Figure 4.[4]

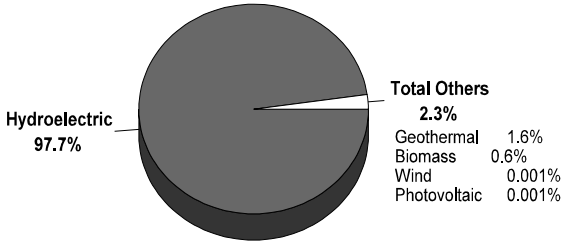

Figure 4. Comparison of the Electricity Generated by the Renewable Sources *(Source: U.S. Department of Energy[4])*

Q **What are the present costs of electricity produced from the major energy sources?**

A The cost of electricity produced by use of each of the major energy sources follows:

- Coal*-2.07 cents per kilowatt-hour (kWh);[5]
- Nuclear*-1.83 cents per kWh;[5]
- Hydropower**-2.4 cents per kWh;[5]
- Natural Gas*-2.84 cents per kWh;[5]
- Oil*-2.41 cents per kWh;[5]
- Geothermal**-7.0 cents per kWh;[6]
- Biomass**-6.0 cents per kWh;[6]
- Wind**-4.0 cents per kWh;[6]
- Solar**-8.5 cents per kWh.[6]

* Includes operation and maintenance costs, but not capital costs.[7] For nuclear and coal plants, the capital costs are approximately the same.[8] The capital costs for a new nuclear plant are 3.2 cents per kWh averaged over 30 years.

** These costs include capital costs, operation and maintenance costs, with a correction for inflation, averaged over the lifetime of the equipment.

Q **How can U.S. carbon dioxide (CO_2) emissions be reduced to below the Kyoto Protocol level?**

A One way to reduce carbon emissions to below the Kyoto Protocol level is to substantially increase the use of alternate energy sources and to decrease the use of the fossil fuels, coal and natural gas, in the production of electricity. Five possible Scenarios are shown in Figure 5 for the increased use of nuclear energy or other alternate energy sources instead of natural gas and coal.[7] Scenario **1** shows the carbon emissions projected on the basis of the assumption that almost half of the existing nuclear capacity will be retired by 2020. On the basis of the assumption that all nuclear generating plants operating in 2000 are maintained with respect to performance and license renewal, Scenario

2 shows that carbon emissions would begin to decrease. Scenario **3** includes the assumptions of Scenario **2** plus the further assumption that nuclear capacity is added in place of projected new coal plants, and a further decline in carbon emissions would be obtained. Scenario **4** includes the assumptions of Scenario **3** plus the further assumption that nuclear plants are added instead of the projected gas plants, and a further decline in carbon emissions would be obtained. Finally Scenario **5** includes the assumptions of Scenario **4** plus the further assumption that all coal plants upon retirement will be replaced by nuclear plants, and this would give a significant decline in carbon emissions as shown in Figure 5.

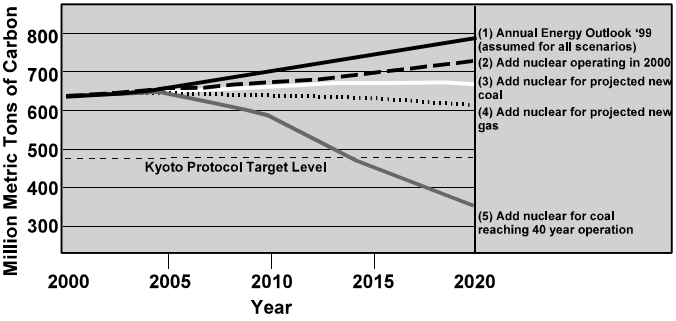

Figure 5. Reducing Carbon Emissions by Use of Nuclear Energy and Other Alternate Energy Sources.[7]

NUCLEAR

Q **What are the major advantages and disadvantages in the use of nuclear energy to produce electricity?**

A ***Advantages:***

- No emissions are associated with the production of electricity.
- The present cost of electricity produced from nuclear energy can be lower than the cost of electricity produced from fossil fuels.
- The use of nuclear energy will reduce some of the dependence of the United States on imported oil.
- There is enough high grade uranium ore to supply all present and future needs of nuclear plants for at least the 21st century.

Disadvantages:

- Since the Chernobyl and Three Mile accidents, public opinion has been so opposed to the use of nuclear energy that no new construction of nuclear power plants has been undertaken. It should be noted, however, that very few large power producing plants of any kind were built in the U.S. during that period because of the general excess of electrical capacity.

However, use of nuclear power is increasing in favor as evidenced by the fact that several nuclear plants that were scheduled to be decommissioned because of age are now requesting an extension of their licenses for another 20 years.

- Suitable storage of spent reactor fuel and disposition of nuclear wastes faces challenges of public acceptance, despite the maturity of underlying technology. The prospects appear good for a high-level storage at the Yucca Mountain site in Nevada by at least 2007 to 2010. Also, research is being carried out on spent fuels to effect a transmutation of those elements of the fuel having long half-lives (in the thousands of years) to elements having relatively short half-lives (in the hundreds of years).
- In the past, nuclear power plants cost more to build than did fossil fuel plants. However, the cost of a nuclear power plant is expected to be about the same as that for a coal-fired plant because there is now a fixed set of regulations for nuclear plants and because the design of new plants has changed to modular form with most of the testing of the modules to be done before transferring them to the plant site.

Q **What is the major difference in the operation of a coal-fired electric generating plant and nuclear power plant?**

A In a **coal-fired plant**, coal is burned to obtain the heat necessary to boil water to produce steam. The steam is used to drive a steam turbine that in turn drives an electric generator that produces electricity.

In a **nuclear power plant**, the heat from a nuclear reaction is used to boil the water to produce the steam. The remainder of the cycle is the same as that for a coal-fired plant.

Q **How does the most commonly used reactor, the pressurized water reactor (PWR) operate?**

A A flow diagram of a pressurized water reactor (PWR) is shown in Figure 6. The water surrounding the ***core*** is kept at a high pressure to prevent it from boiling at the high temperature of the core. This ***water*** is circulated through a closed loop, called the ***primary loop***. After it has passed through the core removing the heat produced by the fission reaction, it passes inside of the tubes through the ***steam generator***. As the high pressure water stream passes through the ***steam generator***, the heat of fission is transferred through the tubes. The high pressure water then returns to the reactor core to begin another cycle of the primary loop. The water on the outside of these tubes is in the ***secondary***

loop. This water is at a much lower pressure than that of the water in the ***primary loop***, and as it passes through the steam generator, it boils to produce steam. The steam in turn drives the ***steam turbine-electric generator***, which generates the electricity.

After the steam has passed through the ***steam turbine***, it goes to the surface ***condenser*** where it is condensed and returned to the steam generator to begin another cycle of the ***secondary loop***. The ***cooling water*** for the surface condenser is drawn from external sources such as lakes, rivers, or the ocean. After it has passed through the surface condenser, it is returned either to the original source or discharged in some appropriate manner. [Water from a 7,000 acre lake is used as cooling water for the surface condenser at the South Texas Project.] In the PWR reactor, the reactor water in the primary loop never comes into direct contact with the uranium inside the rods or with the water in the secondary loop. Also, the water in the secondary loop never comes in contact with the surface cooling water.

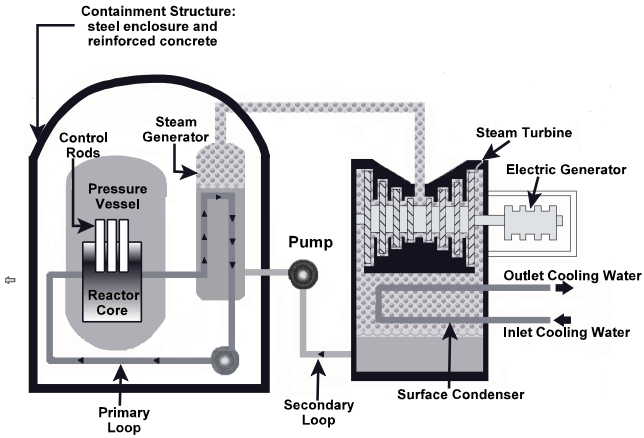

Figure 6. Flow Diagram of a Pressurized Water Reactor (PWR)[8,9]

Q **What is the nuclear reaction that is carried out in present day nuclear power plants?**

A This nuclear reaction consists of an atom of uranium-235 being struck by a neutron (a subatomic particle). After having been struck, the uranium-235 splits (fissions) into fission products.

The mass of the fission products is less than the mass of the reactants (the atom uranium-235 and a neutron). The difference of mass is converted into energy, and this energy is used to boil the water to produce the steam.

Q **Is a nuclear explosion like the atomic bomb possible in a reactor?**

A No. According to the scientists, the fuel in a reactor does not contain enough uranium-235 (U-235) to cause an explosion. The explanation given is that the mixture must contain far more than 3% U-235. Next it has to be arranged in shape such that the probability is maximized that each neutron emitted will strike another atom of U-235. A spherical arrangement is the optimum configuration to achieve this condition. When the two parts of a sphere of highly enriched uranium are brought together, the mass becomes supercritical and will explode provided that the fuel is sufficiently rich in U-235.

Q **What is the possibility of occurrence of nuclear accidents such as the Three Mile Island and Chernobyl?**

A It is generally believed by the most knowledgeable people that with today's reactor design, neither of these events can occur.[10,11]

Q **How did Chernobyl and Three Mile Island accidents differ?**

A The Chernobyl accident killed 31 people and the contamination of the land over an 18 mile radius was substantial. However, there is no evidence at this time that any of the subsequent deaths in this area were directly related to cancer that could have been caused by the Chernobyl exposure.

The Three Mile accident was unlike the Chernobyl accident in that it led to no deaths or injuries to plant workers or members of the surrounding community. Although low levels of radiation were released, they were so low that the chance of anyone within a 50 mile radius developing cancer was infinitesimal. However, like the Chernobyl accident, the Three Mile Island accident did create fear and distrust of nuclear plants by the public.

Q **What is the status of the storage of the spent reactor fuel from nuclear power plants, and how much is there to be stored?**

A The storage site at Yucca Mountain in Nevada is under study by the Department of Energy, and it appears that the opening date for the repository will not be before 2007 to

2010.

Fortunately, the volume of spent nuclear reactor fuel is small. All of the spent fuel generated by all U.S. nuclear reactors since they were started up in the early 1960's amounts to approximately 40,000 tons, which would cover a football field to a height of about four yards.[3] Also research is being conducted on the spent fuel to effect a transmutation of those elements of fuel having half-lives in the thousands of years into elements having half-lives in the hundreds of years.

Q **How is the spent fuel to be stored at Yucca Mountain, Nevada?**

A Present plans are to convert the spent fuel into glass. Glass is the form generally selected because it is one of the most stable of all materials. According to Waltar, samples of glass from the Babylonian era (3000 years ago) have been found submerged in water and still intact.[13] Figure 7 shows how a waste package might fit into permanent storage.[13] The glass for the high-level waste (denoted by **1** in Figure 7) is placed in a corrosion resistant canister **2**. The canister is covered with an overpack of low solubility **3**, which is in turn covered with insoluble crushed rock **4**, which is in turn placed in the host rock **5**.

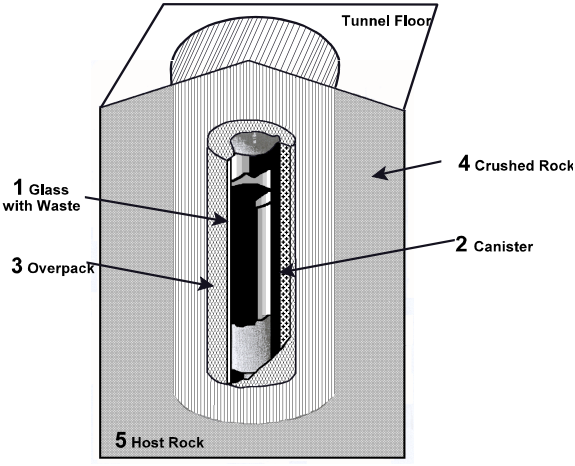

Figure 7. Typical Package of High-Level Waste Sealed in the Sable Geologic Formation in Yucca Mountain
(Source: Waltar, A.E. "American the Powerless," Cogito Books, 1995)

HYDROPOWER

Q **What are some of the advantages and disadvantages of producing electricity by use of hydropower?**

A

Advantages:

- No emissions are produced in the generation of electricity.
- The cost of electricity produced by hydropower is among the lowest costs of electricity produced from a renewable energy source.

Disadvantages:

- Most of the appropriate sites for dams already have dams built on them.
- The hydroelectric power dams can have a detrimental impact on wildlife and habitat downstream from the dam. Present dams are being designed to minimize this impact.
- Construction of dams destroy forests and habitats.
- The turbines can kill fish. New turbine designs and other techniques are being devised to minimize fish kills.
- Hydropower dams are thought to reduce or stop the migration of salmon to their spawning grounds, contributing to the decline of salmon.
- Seasonal shortages of rain or snowfall will limit the ability to meet both power and energy needs.
- Dams present easy targets for aerial terrorism.

Q **How does the United States rank with other countries in the production of electricity by use of hydropower?**

A The United States is the world's leading hydropower producer.[3] The largest U.S. hydropower plant is the Grand Coulee station on the Columbia River in Washington State. This plant is being upscaled to 10,800 MW that will make it the second largest next to Brazil's 13,320 MW plant, the largest plant in the world.

Q **How does a typical hydroelectric plant work?**

A Figure 8 shows the sketch of a typical hydroelectric plant. As shown the water flows from the top of the water surface of the dam to the turbine. The water passes down through the turbine turning it. The turbine turns an electric generator that generates electricity.

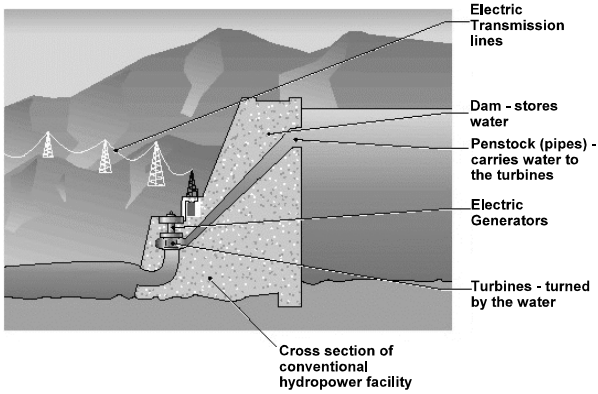

Figure 8. Cross-sectional View of a Conventional Hydroelectric Facility *(Source: U.S. Department of Energy[14])*

GEOTHERMAL

Q **What is the source of all geothermal energy?**

A The source of geothermal energy is the magma that is located beneath the outer crust of the Earth. In certain parts of the Earth, the magma is near the surface. In the United States, most of the high-energy level geothermal reservoirs are located in the western states, Alaska, and Hawaii. These areas of high-energy levels are generally in the neighborhood of 400°F. There are low-energy level geothermal sources which consists of the Earth at about 50 feet below the surface where the temperature remains at 50° to 60°F the year round.

Q **How are the geothermal sources of high- and low-energy levels used?**

A The high-energy level sources are used as the heat source to boil water to produce steam that in turn drives a steam-electric generator to produce electricity.

The low-energy sources are used as a heat source by heat pumps for heating a house in the winter and as a heat sink to cool a house in the summer.

Q **What are some of the advantages and disadvantages of geothermal energy?**

A ***Advantages:***

- The present geothermal energy sources are expected to last indefinitely.
- Almost no emissions are produced in the generation of

electricity. Technology for practically eliminating the impact of the emissions has been developed and is in place.

Disadvantages:

- High temperature geothermal sources for the production of electricity are to be found only in the western states, Alaska, and Hawaii. Thus, the generation of electricity from geothermal energy is not expected to increase substantially.
- Corrosion problems can be encountered in recovering high-level geothermal energy.

BIOMASS

Q **What are some of the sources of biomass?**

A Biomass is available in the form of wood, wood wastes, residues from the wood products industry, the organic portion of municipal wastes, animal manures, wastes from plant processing industries, and fast growing trees and crops.

Q **How is biomass used to produce electrical energy?**

A Biomass is burned in a boiler to produce high pressure steam. The steam is used as in any power plant to turn a turbine connected to an electric generator that produces electricity.

Q **What are some of the advantages and disadvantages of biomass as an energy source?**

A ***Advantages:***

- In many cases, the biomass is a waste that must be disposed of, and the use of it as a fuel to generate electricity can prove both useful and economical.
- Nearly any biomass: corn, wheat, soybeans, wood can be used to produce useful chemicals such as ethanol, cornstarch and a variety of plastics. Any of the biowaste from these processes can be used to generate electricity.
- The burning of biomass in the production of electricity is at best a break-even situation with respect to carbon dioxide emissions in that the carbon dioxide absorbed in growing the biomass is approximately equal to the carbon dioxide produced upon burning the biomass.

Disadvantages:

- When used to produce steam for electrical generation, the cost of gathering the biomass can become a significant expense.

- Oxides of nitrogen can be produced, depending on the combustion temperature of the biomass.
- Wider use of biomass may displace other uses of the land or displace wildlife.

WIND ENERGY

Q **How does Texas rank with other states in potential wind energy, and what percentage of the nation's energy needs could be supplied by wind?**

A Texas ranks second to North Dakota in its potential for supplying wind energy. Wind has the potential for supplying 20% of the nation's electricity needs.[6]

Q **What is the present status of electricity generation from wind energy, and what are the plans and potential of wind energy in Texas?**

A Texas has 188.54 megawatts(MG) of installed wind-electric generation and has plans for an additional 919.78 MW.

At the present time there are eight wind farms or areas with wind-electric generators, and 11 more wind-electric generator projects are planned.

Q **What are some of the advantages and disadvantages of the use of wind energy to generate electricity?**

A ***Advantages:***

- Wind energy is free and an inexhaustible source.
- Today's wind turbines are highly sophisticated power systems relative to the windmills of the past. They are equipped with modern mechanical drive systems connected to advanced generators that produce electricity.
- Wind farms consisting of wind turbine-generators do not interfere with agricultural operations.

Disadvantages:

- Since the wind does not blow all of the time, wind systems require a secondary electrical supply source such as an electrical utility for continuous operation.
- Only a limited number of locations are suitable for wind power systems because there are a limited number of areas where the wind blows with sufficient velocity to produce electricity.
- There have been complaints about the noise produced by the wind turbines.
- Some birds have been killed by the large blades of the turbine, but new turbine designs for towers are

eliminating places for birds to sit and this reduces the bird mortality.

SOLAR ENERGY

Q **What is the major problem in using solar energy to produce electricity?**

A The major problem is capturing and harnessing the suns rays.

Q **What are some of the systems being used to capture and harness the sun's rays?**

A *Solar Trough* systems consist of parabolic troughs that collect the sun's rays and reflect them onto a pipe located along the focal line of the trough. The pipe contains a heat transfer oil, which reaches temperatures as high as 735°F.[15]

A *Solar Power Tower* operates in a similar manner to the trough except that in this case the rays are reflected onto a centrally located tower filled with heat transfer fluid, which reaches temperatures as high as 1050°F.[16]

In the case of both the tower and the trough, the hot heat transfer fluid is passed to a steam generator and the steam produced is sent to a conventional steam turbine-electric generator.

A third method of capturing the sun's energy is by use of photovoltaic cells. When sunlight shines on these cells, it causes a direct current (DC) to flow. This DC current may be used directly, stored in a battery or converted by use of an inverter to alternating current (AC) before using.

Q **What are some of the advantages and disadvantages of solar energy in the generation of electricity?**

A ***Advantages:***

- The versatility of solar energy makes it suitable for both large and small applications in the production of electricity.
- Solar energy is free and finds many uses ranging from calculators, space craft to solar electric power plants. These applications range from those requiring a few hundred kilowatts up to those requiring 400 megawatts (MW) or more.

Disadvantages:

- Solar energy is an intermittent source because the sun does not shine all of the time. Thus these energy

systems must be coupled with a supplementary source of power for continuous production of electricity.

- Solar energy is a diffuse energy source, and the cost of collecting it makes its cost the highest of the renewable energy sources. However, this price may not be prohibitive for its use as a supplementary source during times of peak power demands.

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