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Solar Energy as the Ultimate Renewable Energy Source

[1]Isizoh A.N., [2]Udegbunam U.E., [3]Ogbogu E.N., [4]Okpala E.U.

[1,2,3,4]Department of Electronic and Computer Engineering, Nnamdi Azikiwe University, Awka, Nigeria

***Abstract* - Renewable energy is an energy that is generated from natural processes that are continuously replenished. This includes solar, geothermal heat, wind, tides, water, and various forms of biomass. Renewable energy cannot be exhausted and is constantly renewed. Solar energy is energy from the sun, and it is considered as the ultimate renewable energy source because it can be used in many applications and it is independent of climatic changes. This paper thus x-rays the background study, principles and applications of solar energy as the ultimate renewable energy source.**

Keywords: Renewable, Solar power, Photovoltaic, Solar Radiation.

I. INTRODUCTION

Renewable energy is sustainable as it is obtained from sources that are inexhaustible (unlike fossil fuels). It includes wind, solar, biomass, geothermal and hydro, all of which occur naturally [1]. Renewable energy, generally speaking, is clean energy and non-polluting. Many forms do not emit any greenhouse gases or toxic waste in the process of producing electricity. It is a sustainable energy source that can be relied upon for long-term applications. Renewable energy is cost-effective and efficient. Solar energy is radiant light and heat from the sun that is harnessed using a range of ever-evolving technologies such as solar heating, photovoltaic, solar thermal energy, solar architecture, molten salt power plants and artificial photosynthesis.

It is an important source of renewable energy and its technologies are broadly characterized as either passive solar or active solar depending on how they capture and distribute solar energy or convert it into solar power [2]. Active solar techniques include the use of photovoltaic systems, concentrated solar power and solar water heating to harness the energy. Passive solar techniques include orienting a building to the Sun, selecting materials with favorable thermal mass or light-dispersing properties, and designing spaces that naturally circulate air.

The large magnitude of solar energy available makes it a highly appealing source of electricity. The United Nations Development Programmed in its 2000 World Energy Assessment found that the annual potential of solar energy was 1,575–49,837 exa-joules (EJ). This is several times larger than the total world energy consumption, which was 559.8 EJ in 2012.

In 2011, the International Energy Agency said that "the development of affordable, inexhaustible and clean solar energy technologies will have huge longer-term benefits. It will increase countries' energy security through reliance on an indigenous, inexhaustible and mostly import-independent resource, enhance sustainability, reduce pollution, lower the costs of mitigating global warming, and keep fossil fuel prices lower than otherwise. These advantages are global. Hence the additional costs of the incentives for early deployment should be considered learning investments; they must be wisely spent and need to be widely shared". The Earth receives 174,000 terawatts (TW) of incoming solar radiation (insulation) at the upper atmosphere. Approximately 30% is reflected back to space while the rest is absorbed by clouds, oceans and land masses. The spectrum of solar light at the Earth's surface is mostly spread across the visible and near-infrared ranges with a small part in the near ultraviolet. Most of the world's population lives in areas with insulation levels of 150-300 watts/m², or 3.5-7.0 kWh/m² per day.

Solar radiation is absorbed by the Earth's land surface, oceans which cover about 71% of the globe – and atmosphere. Warm air containing evaporated water from the oceans rises, causing atmospheric circulation or convection. When the air reaches a high altitude, where the temperature is low, water vapor condenses into clouds, which rain onto the Earth's surface, completing the water cycle. The latent heat of water condensation amplifies convection, producing atmospheric phenomena such as wind, cyclones and anti-cyclones. Sunlight absorbed by the oceans and land masses keeps the surface at an average temperature of 14 °C. By photosynthesis, green plants convert solar energy into chemically stored energy, which produces food, wood and the biomass from which fossil fuels are derived [3].

The total solar energy absorbed by Earth's atmosphere, oceans and land masses is approximately 3,850,000 exa-joules (EJ) per year. In 2002, this was more energy in one hour than the world used in one year. Photosynthesis captures approximately 3,000 EJ per year in biomass. The amount of solar energy reaching the surface of the planet is so vast that in one year it is about twice as much as will ever be obtained from all of the Earth's non-renewable resources of coal, oil, natural gas, and mined uranium combined.

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Solar energy may have had great potential, but it was left on the backburner whenever fossil fuels were more affordable and available. "Only in the last few decades when growing energy demands, increasing environmental problems and declining fossil fuel resources made us look to alternative energy options have we focused our attention on truly exploiting this tremendous resource." For instance, the US Department of Energy funded the installation and testing of over 3,000 PV systems during the 1973-1974 oil embargo. By the late 1970s, energy companies and government agencies had invested in the PV industry, and "a tremendous acceleration in module development took place." Solar energy improvements were again sought during the Gulf War in the 1990s.

Considering that "the first practical solar cells were made less than 30 years ago," we have come a long way. The profligation of solar professional companies designing unique and specific solar power systems for individual homes, means there is no longer an excuse not to consider solar power for your home. The biggest jumps in efficiency came "with the advent of the transistor and accompanying semiconductor technology." The production cost has fallen to nearly 1/300 of what it was during the space program of the mid-century and the purchase cost has gone from $200 per watt in the 1950s to a possible mere $1 per watt today. The efficiency has increased dramatically to 40.8% the US Department of Energy's National Renewable Energy Lab's new world record as of August 2008.

We still use solar power in the same two forms today, thermal and photovoltaic. The first concentrates sunlight, converts it into heat, and applies it to a steam generator or engine to be converted into electricity in order "to warm buildings, heat water, generate electricity, dry crops or destroy dangerous waste." Electricity is generated when the heated fluid drives turbines or other machinery. The second form of solar power produces electricity directly without moving parts. Today's photovoltaic system is composed of cells made of silicon, the second most abundant element in the earth's crust. "Power is produced when sunlight strikes the semiconductor material and creates an electric current." The smallest unit of the system is a cell. Cells wired together form a module, and modules wired together form a panel. A group of panels is called an array, and several arrays form an array field [4].

There are several advantages of photovoltaic solar power that make it "one of the most promising renewable energy sources in the world." It is non-polluting, has no moving parts that could break down, requires little maintenance and no supervision, and has a life of 20-30 years with low running costs. It is especially unique because no large-scale installation is required. Remote areas can easily produce their own supply of electricity by constructing as small or as large of a system as needed. Solar power generators are simply distributed to homes, schools, or businesses, where their assembly requires no extra development or land area and their function is safe and quiet. As communities grow, more solar energy capacity can be added, "thereby allowing power generation to keep in step with growing needs without having to overbuild generation capacity as is often the case with conventional large scale power systems." Compare those characteristics to those of coal, oil, gas, or nuclear power, and the choice is easy. Solar energy technologies offer a clean, renewable and domestic energy source.

Photovoltaic power even has advantages over wind power, hydropower, and solar thermal power [5]. The latter three require turbines with moving parts that are noisy and require maintenance. Solar energy is most sought today in developing countries, the fastest growing segment of the photovoltaic’s market. People go without electricity as the sun beats down on the land, making solar power the obvious energy choice. "Governments are finding its modular, decentralized character ideal for filling the electric needs of the thousands of remote villages in their countries." It is much more practical than the extension of expensive power lines into remote areas, where people do not have the money to pay for conventional electricity.

Solar power is just as practical in populated areas connected to the local electrical power grid as it is in remote areas. "An average home has more than enough roof area to produce enough solar electricity to supply all of its power needs. With an inverter, which converts direct current (DC) power from the solar cells to alternating current (AC), which is what most home appliances run on, a solar home can look and operate very much like a home that is connected to a power line" [6].

Household energy supply is but one use of solar power. There are actually four broad categories that can be identified for solar energy use: industrial, rural habitation, grid-connected, and consumer/indoor. Industrial uses represent the largest applications of solar power in the past 30 years. "Telecommunications, oil companies, and highway safety equipment all rely on solar power for dependable, constant power far from any power lines." Roadside call boxes and lighted highway signs rely on the sun's energy in order to provide reliable services without buried cable connections or diesel generators. Navigational systems such as marine buoys and other unmanned installations in harsh remote areas are also ideal applications for solar power because "the load demands are well known and the requirements for reliable power are the highest." Rural habitation includes "cabins, homes, villages, clinics, schools, farms, as well as individually

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powered lights and small appliances." Grid-connected systems pair solar power with an existing grid network in order to supply a commercial site with enough energy to meet a high demand, or to supplement a family's household supply [7]. Consumer/indoor uses of PV cells include watches and calculators; PV modules power computers and radios.

The practicality and environmentally safe nature of solar power is influencing people worldwide, which is evident in equipment sales. According to Siemens' Solar, production of PV cells and modules increased threefold from 40 MW in 1990 to about 120 MW in 1998. "Worldwide sales have been increasing at an average rate of about 15% every year during the last decade.

We believe that there is a realistic possibility for the market to continue to grow at about a 15% rate into the next decade. At this rate, the world production capacity would be 1000 MW by 2020, and photovoltaics could be a $5 billion industry." There are only two primary disadvantages to using solar power: amount of sunlight and cost of equipment [8]. The amount of sunlight a location receives "varies greatly depending on geographical location, time of day, season and clouds. The southwestern United States is one of the world's best areas for sunlight. Globally, other areas receiving very high solar intensities include developing nations in Asia, Africa and Latin America".

But a person living in Siberia would not benefit much from this renewable resource. And while "solar energy technologies have made huge technological and cost improvements, they are still more expensive than traditional energy sources." However solar equipment will eventually pay for itself in 2 to 5 years depending on how much sun a particular location receives. Then the user will have a virtually free energy source until the end of the equipment's working life, according to a paper called "Energy Payback Time of Crystalline Silicon Solar Modules." Future improvements are projected to decrease the payback time to 1 to 3 years. As the price of solar power lowers and that of conventional fuels rises, photovoltaic "is entering a new era of international growth." So much so, that solar power "will remain an excellent energy option, long after the momentary fossil fuel model fades into smoke."

Yearly solar fluxes & human consumption[1]	
Solar	3,850,000
Wind	2,250
Biomass potential	~200
Primary energy use[2]	539
Electricity[2]	~67

[1] Energy given in Exa-joule (EJ) = 10^{18} J = 278 TWh
[2] Consumption as of year 2018

The potential solar energy that could be used by humans differs from the amount of solar energy present near the surface of the planet because factors such as geography, time variation, cloud cover, and the land available to humans limit the amount of solar energy that we can acquire [7].

Geography affects solar energy potential because areas that are closer to the equator have a greater amount of solar radiation. However, the use of photovoltaic's that can follow the position of the sun can significantly increase the solar energy potential in areas that are farther from the equator. Time variation affects the potential of solar energy because during the nighttime there is little solar radiation on the surface of the Earth for solar panels to absorb. This limits the amount of energy that solar panels can absorb in one day. Cloud cover can affect the potential of solar panels because clouds block incoming light from the sun and reduce the light available for solar cells [9].

In addition, land availability has a large effect on the available solar energy because solar panels can only be set up on land that is otherwise unused and suitable for solar panels. Roofs have been found to be a suitable place for solar cells, as many people have discovered that they can collect energy directly from their homes this way. Other areas that are suitable for solar cells are lands that are not being used for businesses where solar plants can be established [10]. Solar technologies are characterized as either passive or active depending on the way they capture, convert and distribute sunlight and enable solar energy to be harnessed at different levels around the world, mostly depending on distance from the equator. Although solar energy refers primarily to the use of solar radiation for practical ends, all renewable energies, other than geothermal power and Tidal power, derive their energy either directly or indirectly from the Sun.

Active solar techniques use photovoltaic's, concentrated solar power, solar thermal collectors, pumps, and fans to convert sunlight into useful outputs [11]. Passive solar techniques include selecting materials with favorable thermal properties, designing spaces that naturally circulate air, and referencing the position of a building to the Sun. Active solar technologies increase the supply of energy and are considered supply side technologies, while passive solar technologies reduce the need for alternate resources and are generally considered demand side technologies [12]. In 2000, the United Nations Development Programme, UN Department of Economic and Social Affairs, and World Energy Council published an estimate of the potential solar energy that could be used by humans each year that took into account factors such as insulation, cloud cover, and the land that is usable by humans. The estimate found that solar energy has a global potential of 1,575–49,837 EJ per year (*see table below*).

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Annual solar energy potential by regions (Exajoules)

Region	North America	Latin America and Caribbean	Western Europe	Central and Eastern Europe	Former Soviet Union	Middle East and North Africa	Sub-Saharan Africa	Pacific Asia	South Asia	Centrally planned Asia	Pacific OECD
Minimum	181.1	112.6	25.1	4.5	199.3	412.4	371.9	41.0	38.8	115.5	72.6
Maximum	7,410	3,385	914	154	8,655	11,060	9,528	994	1,339	4,135	2,263

Note:

- Total global annual solar energy potential amounts to 1,575 EJ (minimum) to 49,837 EJ (maximum)
- Data reflects assumptions of annual clear sky irradiance, annual average sky clearance, and available land area. All figures given in Exajoules

Quantitative relation of global solar potential vs. the world's primary energy consumption:

- Ratio of potential vs. current consumption (402 EJ) as of year: 3.9 (minimum) to 124 (maximum)
- Ratio of potential vs. projected consumption by 2050 (590–1,050 EJ): 1.5–2.7 (minimum) to 47–84 (maximum)
- Ratio of potential vs. projected consumption by 2100 (880–1,900 EJ): 0.8–1.8 (minimum) to 26–57 (maximum)

Source: United Nations Development Programme – World Energy Assessment (2016)

II. USES OF SOLAR ENERGY AS THE ULTIMATE RENEWABLE ENERGY SOURCE

The applications of solar energy as the ultimate renewable energy source are explained below:

1) Water heating

Solar hot water systems use sunlight to heat water. In low geographical latitudes (below 40 degrees) from 60 to 70% of the domestic hot water use with temperatures up to 60 °C can be provided by solar heating systems. The most common types of solar water heaters are evacuated tube collectors (44%) and glazed flat plate collectors (34%) generally used for domestic hot water; and unglazed plastic collectors (21%) used mainly to heat swimming pools [8].

2) Heating, cooling and ventilation

Thermal mass is any material that can be used to store heat—heat from the Sun in the case of solar energy. Common thermal mass materials include stone, cement and water. Historically they have been used in arid climates or warm temperate regions to keep buildings cool by absorbing solar energy during the day and radiating stored heat to the cooler atmosphere at night. However, they can be used in cold temperate areas to maintain warmth as well. The size and placement of thermal mass depend on several factors such as climate, day lighting and shading conditions. When properly incorporated, thermal mass maintains space temperatures in a comfortable range and reduces the need for auxiliary heating and cooling equipment.

A solar chimney (or thermal chimney, in this context) is a passive solar ventilation system composed of a vertical shaft connecting the interior and exterior of a building. As the chimney warms, the air inside is heated causing an updraft that pulls air through the building. Performance can be improved by using glazing and thermal mass materials in a way that mimics greenhouses.

Deciduous trees and plants have been promoted as a means of controlling solar heating and cooling. When planted on the southern side of a building in the northern hemisphere or the northern side in the southern hemisphere, their leaves provide shade during the summer, while the bare limbs allow light to pass during the winter. Since bare, leafless trees shade 1/3 to 1/2 of incident solar radiation, there is a balance between the benefits of summer shading and the corresponding loss of winter heating. In climates with significant heating loads, deciduous trees should not be planted on the Equator-facing side of a building because they will interfere with winter solar availability. They can, however, be used on the east and west sides to provide a degree of summer shading without appreciably affecting winter solar gain.

Solar cookers use sunlight for cooking, drying and pasteurization. They can be grouped into three broad categories: box cookers, panel cookers and reflector cookers. The simplest solar cooker is the box cooker first built by Horace de Saussure in 1767. A basic box cooker consists of an insulated container with a transparent lid. It can be used effectively with partially overcast skies and will typically reach temperatures of 90–150 °C (194–302 °F). Panel cookers use a reflective panel to direct sunlight onto an insulated container and reach temperatures comparable to box cookers. Reflector cookers use various concentrating geometries (dish, trough, Fresnel mirrors) to focus light on a cooking container. These cookers reach temperatures of 315 °C (599 °F) and

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above but require direct light to function properly and must be repositioned to track the Sun.

3) Process heat

Solar concentrating technologies such as parabolic dish, trough and Scheffler reflectors can provide process heat for commercial and industrial applications. The first commercial system was the Solar Total Energy Project (STEP) in Shenandoah, Georgia, USA where a field of 114 parabolic dishes provided 50% of the process heating, air conditioning and electrical requirements for a clothing factory. This grid-connected cogeneration system provided 400 kW of electricity plus thermal energy in the form of 401 kW steam and 468 kW chilled water, and had a one-hour peak load thermal storage. Evaporation ponds are shallow pools that concentrate dissolved solids through evaporation. The use of evaporation ponds to obtain salt from seawater is one of the oldest applications of solar energy. Modern uses include concentrating brine solutions used in leach mining and removing dissolved solids from waste streams. Clothes lines, clotheshorses, and clothes racks dry clothes through evaporation by wind and sunlight without consuming electricity or gas. In some states of the United States legislation protects the "right to dry" clothes. Unglazed transpired collectors (UTC) are perforated sun-facing walls used for preheating ventilation air. UTCs can raise the incoming air temperature up to 22 °C (40 °F) and deliver outlet temperatures of 45–60 °C (113–140 °F).

4) Water treatment

Solar distillation can be used to make saline or brackish water potable. The first recorded instance of this was by 16th-century Arab alchemists. A large-scale solar distillation project was first constructed in 1872 in the Chilean mining town of Las Salinas. The plant, which had solar collection area of 4,700 m2 (51,000 sq ft), could produce up to 22,700 L (5,000 imp gal; 6,000 US gal) per day and operate for 40 years. Individual still designs include single-slope, double-slope (or greenhouse type), vertical, conical, inverted absorber, multi-wick, and multiple effect. These stills can operate in passive, active, or hybrid modes. Double-slope stills are the most economical for decentralized domestic purposes, while active multiple effect units are more suitable for large-scale applications [9].

Solar water disinfection (SODIS) involves exposing water-filled plastic polyethylene terephthalate (PET) bottles to sunlight for several hours. Exposure times vary depending on weather and climate from a minimum of six hours to two days during fully overcast conditions. It is recommended by the World Health Organization as a viable method for household water treatment and safe storage. Over two million people in developing countries use this method for their daily drinking water. Solar energy may be used in a water stabilization pond to treat waste water without chemicals or electricity. A further environmental advantage is that algae grow in such ponds and consume carbon dioxide in photosynthesis, although algae may produce toxic chemicals that make the water unusable.

5) Molten salt technology

Molten salt can be employed as a thermal energy storage method to retain thermal energy collected by a solar tower or solar trough of a concentrated solar power plant, so that it can be used to generate electricity in bad weather or at night [10]. It was demonstrated in the Solar Two project from 1995–1999. The system is predicted to have an annual efficiency of 99%, a reference to the energy retained by storing heat before turning it into electricity, versus converting heat directly into electricity. The molten salt mixtures vary. The most extended mixture contains sodium nitrate, potassium nitrate and calcium nitrate. It is non-flammable and nontoxic, and has already been used in the chemical and metals industries as a heat-transport fluid, so experience with such systems exists in non-solar applications.

The salt melts at 131 °C (268 °F). It is kept liquid at 288 °C (550 °F) in an insulated "cold" storage tank. The liquid salt is pumped through panels in a solar collector where the focused sun heats it to 566 °C (1,051 °F). It is then sent to a hot storage tank. This is so well insulated that the thermal energy can be usefully stored for up to a week.

When electricity is needed, the hot salt is pumped to a conventional steam-generator to produce superheated steam for a turbine/generator as used in any conventional coal, oil, or nuclear power plant. A 100-megawatt turbine would need a tank about 9.1 meters (30 ft) tall and 24 meters (79 ft) in diameter to drive it for four hours by this design. Several parabolic trough power plants in Spain and solar power tower developer Solar Reserve use this thermal energy storage concept. The Solana Generating Station in the U.S. has six hours of storage by molten salt.

Solar power is the conversion of sunlight into electricity, either directly using photovoltaic's (PV), or indirectly using concentrated solar power (CSP). CSP systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. PV converts light into electric current using the photoelectric effect.

6) Concentrated solar power

Concentrating Solar Power (CSP) systems use lenses or mirrors and tracking systems to focus a large area of sunlight into a small beam. The concentrated heat is then used as a heat

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source for a conventional power plant. A wide range of concentrating technologies exists; the most developed are the parabolic trough, the concentrating linear fresnel reflector, the Stirling dish and the solar power tower. Various techniques are used to track the Sun and focus light. In all of these systems a working fluid is heated by the concentrated sunlight, and is then used for power generation or energy storage [11].

7) Agriculture and horticulture

Agriculture and horticulture seek to optimize the capture of solar energy in order to optimize the productivity of plants. Techniques such as timed planting cycles, tailored row orientation, staggered heights between rows and the mixing of plant varieties can improve crop yields. While sunlight is generally considered a plentiful resource, the exceptions highlight the importance of solar energy to agriculture. During the short growing seasons of the Little Ice Age, French and English farmers employed fruit walls to maximize the collection of solar energy. These walls acted as thermal masses and accelerated ripening by keeping plants warm. Early fruit walls were built perpendicular to the ground and facing south, but over time, sloping walls were developed to make better use of sunlight. In 1699, Nicolas Fatio de Duillier even suggested using a tracking mechanism which could pivot to follow the Sun. Applications of solar energy in agriculture aside from growing crops include pumping water, drying crops, brooding chicks and drying chicken manure. More recently the technology has been embraced by vintners, who use the energy generated by solar panels to power grape presses.

Greenhouses convert solar light to heat, enabling year-round production and the growth (in enclosed environments) of specialty crops and other plants not naturally suited to the local climate. Primitive greenhouses were first used during Roman times to produce cucumbers year-round for the Roman emperor Tiberius. The first modern greenhouses were built in Europe in the 16th century to keep exotic plants brought back from explorations abroad. Greenhouses remain an important part of horticulture today, and plastic transparent materials have also been used to similar effect in polytunnels and row covers [12].

8) Transport

Development of a solar-powered car has been an engineering goal since the 1980s. The World Solar Challenge is a biannual solar-powered car race, where teams from universities and enterprises compete over 3,021 kilometers (1,877 mi) across central Australia from Darwin to Adelaide. In 1987, when it was founded, the winner's average speed was 67 kilometers per hour (42 mph) and by 2007 the winner's average speed had improved to 90.87 kilometers per hour (56.46 mph). The North American Solar Challenge and the planned South African Solar Challenge are comparable competitions that reflect an international interest in the engineering and development of solar powered vehicles. Some vehicles use solar panels for auxiliary power, such as for air conditioning, to keep the interior cool, thus reducing fuel consumption.

In 1975, the first practical solar boat was constructed in England. By 1995, passenger boats incorporating PV panels began appearing and are now used extensively. In 1996, Kenichi Horie made the first solar-powered crossing of the Pacific Ocean, and the Sun21 catamaran made the first solar-powered crossing of the Atlantic Ocean in the winter of 2006–2007. There were plans to circumnavigate the globe in 2010.

In 1974, the unmanned Astro Flight Sunrise airplane made the first solar flight. On 29 April 1979, the Solar Riser made the first flight in a solar-powered, fully controlled, man-carrying flying machine, reaching an altitude of 40 feet (12 m). In 1980, the Gossamer Penguin made the first piloted flights powered solely by photovoltaics. This was quickly followed by the Solar Challenger which crossed the English Channel in July 1981. In 1990 Eric Scott Raymond in 21 hops flew from California to North Carolina using solar power. Developments then turned back to unmanned aerial vehicles (UAV) with the Pathfinder (1997) and subsequent designs, culminating in the Helios which set the altitude record for a non-rocket-propelled aircraft at 29,524 meters (96,864 ft) in 2001. The Zephyr, developed by BAE Systems, is the latest in a line of record-breaking solar aircraft, making a 54-hour flight in 2007, and month-long flights were envisioned by 2010. As of 2016, Solar Impulse, an electric aircraft, is currently circumnavigating the globe. It is a single-seat plane powered by solar cells and capable of taking off under its own power. The design allows the aircraft to remain airborne for several days.

A solar balloon is a black balloon that is filled with ordinary air. As sunlight shines on the balloon, the air inside is heated and expands causing an upward buoyancy force, much like an artificially heated hot air balloon. Some solar balloons are large enough for human flight, but usage is generally limited to the toy market as the surface-area to payload-weight ratio is relatively high.

9) Fuel production

Solar chemical processes use solar energy to drive chemical reactions. These processes offset energy that would otherwise come from a fossil fuel source and can also convert solar energy into storable and transportable fuels. Solar induced chemical reactions can be divided into thermo chemical or photochemical. A variety of fuels can be produced

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by artificial photosynthesis. The multi electron catalytic chemistry involved in making carbon-based fuels (such as methanol) from reduction of carbon dioxide is challenging; a feasible alternative is hydrogen production from protons, though use of water as the source of electrons (as plants do) requires mastering the multi electron oxidation of two water molecules to molecular oxygen.

Some have envisaged working solar fuel plants in coastal metropolitan areas by 2050 – the splitting of sea water providing hydrogen to be run through adjacent fuel-cell electric power plants and the pure water by-product going directly into the municipal water system. Another vision involves all human structures covering the earth's surface (i.e., roads, vehicles and buildings) doing photosynthesis more efficiently than plants.

Hydrogen production technologies have been a significant area of solar chemical research since the 1970s. Aside from electrolysis driven by photovoltaic or photochemical cells, several thermo chemical processes have also been explored. One such route uses concentrators to split water into oxygen and hydrogen at high temperatures (2,300–2,600 °C or 4,200–4,700 °F). Another approach uses the heat from solar concentrators to drive the steam reformation of natural gas thereby increasing the overall hydrogen yield compared to conventional reforming methods. Thermo chemical cycles characterized by the decomposition and regeneration of reactants present another avenue for hydrogen production. The Solzinc process under development at the Weizmann Institute of Science uses a 1 MW solar furnace to decompose zinc oxide (ZnO) at temperatures above 1,200 °C (2,200 °F). This initial reaction produces pure zinc, which can subsequently be reacted with water to produce hydrogen.

III. CONCLUSION

Renewable energy is energy generated from natural resources such as solar, wind, rain, tides and geothermal heat which are renewable (naturally replenished). While renewable energy is plentiful, most of the environmental impact is related to the production of equipment to harness the energy.

Solar energy is however the ultimate renewable energy source since all energies comes from the sun, and it is replenish able. It is a free, inexhaustible resource, yet harnessing it is a relatively new idea. It is anticipated to become the world's largest source of electricity by 2050, with solar photovoltaics and concentrated solar power contributing 16 and 11 percent to the global overall consumption, respectively.

The earth receives an incredible supply of solar energy. The sun, an average star, is a fusion reactor that has been burning over 4 billion years. It provides enough energy in one minute to supply the world's energy needs for one year. In one day, it provides more energy than our current population would consume in 27 years. In fact, "The amount of solar radiation striking the earth over a three-day period is equivalent to the energy stored in all fossil energy sources."

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