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Green chemistry and green energy technologies for environmental friendly sustainable development

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Abstract

The fundamental fact remains that the World has entered a new age of energy, and we have not yet adjusted our habits, expectations, and national policies to the new age. Therefore, the green or renewable energy sources has important role for environmental friendly sustainable development. Green energy sources obtained from the power of the sun's radiation are at once the most ancient and the most modern forms of energy used by humanity. Solar power, both in the form of direct solar radiation and in indirect forms such as bioenergy, water and wind power, was the energy source upon which early human societies were based. Societies went on to develop ways of harnessing the movements of water and wind power for irrigation and electricity generation. In last two decades, architects began to design buildings to take advantage of the Sun's energy by enhancing their natural use of its heat and light. On the other hand, chemical materials and chemical industry has been growing very quickly for two decades. But, toxic chemicals are very harmful for human health and natural environment. This review shows that green chemistry or less toxic chemicals and green energy technologies are very important for environmental pollution prevention activities.

Keywords: green chemistry; renewables; green energy; sustainable development.

1. Introduction

Energy, the ability to accomplish physical work, comes to our attention principally as an input for economic processes and as an intermediate good. It is rare to find energy demanded for its own sake. Energy is usually valued as an input in some processes of production or utilization which results in a final product [1]. On the other hand, economic development has gone hand in hand with increased energy used per capita, beginning in history with solar energy embodied in plants and animals, and continuing through draft animals, wind energy, and fossil fuels. Energy input always produces some measure of pollution, since waste products occur along with the desired goods [2].

Renewable energy sources, derived principally from the enormous power of the Sun's radiation, are at once the most ancient and the most modern forms of energy used by humanity [3, 4]. Solar power, both in the form of direct solar radiation and in indirect forms such as bioenergy, water or wind power, was the energy source upon which early human societies were based [5, 6]. When our ancestors first used fire, they were harnessing the power of photosynthesis, the solar-driven process by which plants are created from water and atmospheric carbon dioxide. Societies went on to develop ways of harnessing the movements of water and wind, both caused by solar heating of the oceans and atmosphere, to grind corn, irrigate crops and propel ships. As civilizations became more sophisticated, architects began to design buildings to take advantage of the Sun's energy by enhancing their natural use of its heat and light, so reducing the need for artificial sources of warmth and illumination [7-9].

Renewable energy sources, being eco-friendly and distributed globally, offer our planet a chance to reduce carbon emissions, clean the air, and serve as essential input for an overall strategy of sustainable development in agriculture, animal husbandry, industry, transportation, domestic uses such as water supply, sanitation, environmental quality, , green energy and sustainable development [4]. The major renewable energy sources are solar, wind, hydropower, geothermal, tidal/wave, biomass and biofuels. In order to achieve the maximum utilization of renewable energy sources and supplies, the primary task, therefore, is to integrate the various forms of renewable energy [5-7].

A transition to renewable energy (or green energy) is inevitable, not because fossil fuel supplies will run out

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but because the costs and risks of using these supplies will continue to increase relative to renewable energy. The present paper reviewed the effect of green chemistry and green energy technologies for environmental friendly sustainable development. This study shows that green chemistry or less toxic chemicals and green energy technologies are very important for environmental pollution prevention activities.

2. Global warming and green chemistry

2.1. Global warming

Solar energy strikes the top of the Earth's atmosphere at a rate of 343 W/m^2. About 30% of this energy is reflected back into space by the Earth or the atmosphere. The Earth–atmosphere system absorbs the remaining energy and re-emits it into space as black-body radiation, with most of the intensity being carried by infrared radiation in the range 200–2500 cm^{-1}. The Earth's average temperature is maintained by an energy balance between solar radiation absorbed by the Earth and black-body radiation emitted by the Earth [8-10].

The trapping of infrared radiation by certain gases in the atmosphere is known as the greenhouse effect, so called because it warms the Earth as if the planet were enclosed in a huge greenhouse [9]. The result is that the natural greenhouse effect raises the average surface temperature well above the freezing point of water and creates an environment in which life is possible. The major constituents to the Earth's atmosphere, O_2 and N_2, do not contribute to the greenhouse effect because homo nuclear diatomic molecules cannot absorb infrared radiation. However, the minor atmospheric gases, water vapor and CO_2, do absorb infrared radiation and hence are responsible for the greenhouse effect. Water vapor absorbs strongly in the ranges 1300–1900 cm^{-1} and 3550–3900 cm^{-1}, whereas CO_2 shows strong absorption in the ranges 500–725 cm^{-1} and 2250–2400 cm^{-1} [9, 10].

Increases in the levels of greenhouse gases, which also include methane, dinitrogen oxide, ozone, and certain chlorofluorocarbons, as a result of human activity have the potential to enhance the natural greenhouse effect, leading to significant warming of the planet. This problem is referred to as global warming, which we now explore in some detail [9]. On the other hand, the concentration of water vapor in the atmosphere has remained steady over time, but concentrations of some other greenhouse gases are rising. From about the year 1000 until about 1750, the CO_2 concentration remained fairly stable, but, since then, it has increased by 28%. The concentration of methane, CH_4, has more than doubled during this time and is now at its highest level for 160 000 years. Studies of air pockets in ice cores taken from Antarctica show that increases in the concentration of both atmospheric CO_2 and CH_4 over the past 160 000 years correlate well with increases in the global surface temperature. Human activities are primarily responsible for the rising concentrations of atmospheric CO_2 and CH_4. Most of the atmospheric CO_2 comes from the burning of hydrocarbon fuels, which began on a large scale with the Industrial Revolution in the middle of the nineteenth century. The additional methane comes mainly from the petroleum industry and from agriculture [9, 10].

The temperature of the surface of the Earth has increased by about 0.5 K since the late nineteenth century. If we continue to rely on hydrocarbon fuels and current trends in population growth and energy are not reversed, then by the middle of the twenty-first century, the concentration of CO_2 in the atmosphere will be about twice its value prior to the Industrial Revolution. The Intergovernmental Panel on Climate Change (IPCC) estimated in 1995 that, by the year 2100, the Earth will undergo an increase in temperature of 3 K [11]. Furthermore, the rate of temperature change is likely to be greater than at any time in the last 10 000 years. To place a temperature rise of 3 K in perspective, it is useful to consider that the average temperature of the Earth during the last ice age was only 6 K colder than at present. Just as cooling the planet can lead to detrimental effects on ecosystems. Computer projections for the next 200 years predict further increases in atmospheric CO_2 levels and suggest that, to maintain CO_2 at its current concentration, we would have to reduce fossil fuel consumption immediately by about 50%. Clearly, in order to reverse global warming trends, we need to develop alternatives to fossil fuels, such as hydrogen and solar technologies [9, 10, 11].

2.2. Green chemistry

The limitations of a command and control system for environmental protection have become more obvious even as the system has become more successful. In industrialized societies with good, well-enforced regulations, most of the easy and inexpensive measures that can be taken to reduce pollution and exposure to harmful chemicals have been implemented. So, small increases in environmental protection now require relatively large investments in money and effort and the better way is through the practice of green chemistry [13-16].

Green chemistry can be defined as the practice of chemical science and manufacturing in a manner that is sustainable, safe, and non-polluting and that consumes minimum amounts of materials and energy while producing little or no waste material. The practice of green chemistry begins with recognition that the production, processing, use, and eventual disposal of chemical products may cause harm when performed incorrectly [16]. In accomplishing its objectives, green chemistry and green chemical engineering may modify or totally redesign chemical products and processes with the objective of minimizing wastes and the use or generation of particularly dangerous materials. Those who practice green chemistry recognize that they are responsible for any effects on the world that their chemicals or chemical processes may have [17]. Far from being economically regressive and a drag on profits, green chemistry is about increasing profits and promoting innovation while protecting human health and the environment [18-20].

The concept of green chemistry has appeared in the science area as a common research program resulting from interdisciplinary cooperation of university teams, independent research groups, industry, scientific societies and governmental agencies, which each have their own programs devoted to decreasing pollution. Green chemistry incorporates a new approach to the synthesis, processing and application of chemical substances in such a manner as to reduce threats to health and the environment [16].

Green chemistry is commonly presented as a set of twelve principles and these principles comprise instructions for chemists to implement new chemical compounds, new syntheses and new technological processes [16]. The first principle describes the basic idea of green chemistry (protecting the environment from pollution). The remaining principles are focused on such issues as atom economy, toxicity, solvent and other media using consumption of energy, application of raw materials from renewable sources and degradation of chemical products to simple, nontoxic substances that are friendly for the environment [18-20].

2.3. Principles of green chemistry

All of the sustainability challenges for chemistry were outlined by Paul Anastas and John Warner in 12 principles, which aim to reduce in as much as possible the toxicity and danger of products and their environmental impact [16, 20, 21].

1. ***Waste prevention:*** It is better to prevent waste than to treat or clean up waste after it has been created, for example greenhouse gases and acid rain.
2. ***Atom economy:*** Synthetic methods should be designed to maximize the incorporation of all materials used in the process into the final product.
3. ***Less hazardous chemical syntheses:*** Wherever practicable, synthetic methods should be designed to use and generate substances that possess little or no toxicity to human health and the environment.
4. ***Designing safer chemicals:*** Chemical products should be designed to effects their desired function while minimizing their toxicity.
5. ***Safer solvents and auxiliaries:*** The use of auxiliary substances should be made unnecessary when possible and innocuous when used.
6. ***Design for energy efficiency:*** Energy requirements of chemical processes should be recognized for their environmental and economic impacts and should be minimized.
7. ***Use of renewable feedstocks:*** A raw material or feedstock should be renewable rather than depleting wherever technically and economically practicable.
8. ***Reduce derivatives:*** Unnecessary derivatization should be minimized, because such steps require additional reagents and can generate waste.
9. ***Catalysis:*** Catalytic reagents are superior to stoichiometric reagents due to a reduction in solvent consumption and in organic waste production from fine chemistry.
10. ***Design for degradation:*** Chemical products should be designed so that at the end of their function they break down into innocuous degradation products and do not persist in the environment.
11. ***Real-time analysis for pollution prevention:*** Analytical methodologies need to be further developed to enable real-time in-process monitoring and control prior to the formation of hazardous substances.
12. ***Inherently safer chemistry for accident prevention:*** substances and forms of substances used in a chemical process should be chosen to minimize the potential for chemical accidents, including releases, explosions and fires.

The selected examples for implementing the 12 principles in laboratory and industry are presented in Table 1 [16].

Table 1. Examples of implementation of green chemistry principles into practise.

Nr	Principle	Examples
1	Prevention	Use of solvent-less sample preparation techniques
2	Atom economy	Hydrogenation of carboxylic acid to aldehydes using solid catalysts
3	Less Hazardous Chemical Synthesis	Adipic acid synthesis by oxidation of cyclohexene using hydrogen peroxide
4	Designing Safer Chemicals	New, less hazardous pesticide
5	Safer Solvents and Auxiliaries	Supercritical fluid extraction, synthesis in ionic liquids
6	Design for Energy Efficiency	Polyolefins-polimer alternative to PWC (polymerization may be carried with lower energy consumption)
7	Use of Renewable Feedstocks	Production of surfactants
8	Reduce Derivatives	On-fiber derivatization vs derivatization in solution in sample preparation
9	Catalysis	Efficient Au(III)-catalyzed synthesis of b-enaminones from 1,3-dicarbonyl compounds and amines
10	Design for Degradation	Synthesis of biodegradable polymers
11	Real-time analysis for Pollution Prevention	Use of in-line analyzers for wastewater monitoring
12	Inherently Safer Chemistry for Accident Prevention	Di-Me carbonate (DMC) is an environmentally friendly substitute for di-Me sulfate and Me halides in methylation

3. Green energy technologies

3.1. Introduction

The heat demand for buildings and industries typically accounts for half of a nation's energy resources. In the development of energy policies, it is therefore crucial to examine the way such heating needs are met. In any society, there are many different heating needs, ranging, for example, from the high-temperature needs of the chemical industry to the low-temperature requirements of buildings. Traditionally, each heating need is treated separately. And with today's modern boilers and furnaces, each heating need can be met with energy efficiencies close to 100%. Surprisingly, such a performance can easily be bettered [1-7].

One of nature's three principles of sustainability is to rely mostly on solar energy. We can get renewable solar energy directly from the sun or indirectly from wind, moving water, and biomass, none of which would exist without direct solar energy. Another form of renewable energy is geothermal energy from the earth's interior. Studies show that with increased and consistent government backing in terms of investments in research and development and subsidies and tax breaks, renewable energy could provide 20% of the world's electricity by 2025 and 50% by 2050 [26]. In 2016, it also got 50% of all of its energy and 89% of its electricity from renewable energy. Several studies show that with a crash program, Turkey could get 20% of its total energy and at least 25% of its electricity from renewable sources by 2020 [5-7].

In some local conditions, utility plants use other renewables such as hydropower, geothermal, biomass, solar and wind energy. Utility plants generally use steam-condensing turbines, gas turbines, and combined cycles. Heat recovery for district heating is a common way to improve overall efficiency; of course local regulations, climatic conditions, and plant location determine the attractiveness of this possibility [29]. On the other hand, most of these sources are inadequate to cover the request of a single site, factory, or building, because they yield only low specific power in standard conditions while the current capital and operating costs are rather high [27]. Nevertheless, in spite of these limitations, renewable sources should be considered in the light of local conditions and efforts always made to exploit them [28-31].

Renewable energy technologies, which produce energy without using fossil fuels, contribute a small but rapidly growing portion of the world's energy portfolio. Worldwide investment in the industry totaled $172 billion in 2016. These technologies have the potential to help meet future energy needs, while also addressing increasing concerns about constraints on traditional energy supplies and the environmental impact of fossil fuels. In addition to increasing capital investment, renewable energy is also receiving increasing attention by policy makers.

3.2. Hydropower

Energy flows in the hydrologic cycle of evaporation, precipitation, and surface runoff of water, and can be harnessed to generate electric power as a renewable manner. The earliest use of water power was in water mills several thousand years ago. By the 16th century, water mills had to be adapted to many process. The use of water falling through a distance, in order to turn a turbine and later an electric generator, began after the general introduction of electric power in Turkey at the end of the 19th century. A simple schematic diagram of a hydroelectric power plant is shown in Figure 1. The water, often stored behind a dam, falls through a height (or head) of distance. The water's potential energy is converted to kinetic energy, and the flowing water turns a water turbine. The rotating shaft of the turbine turns the electric generator, which yields the electricity [7].

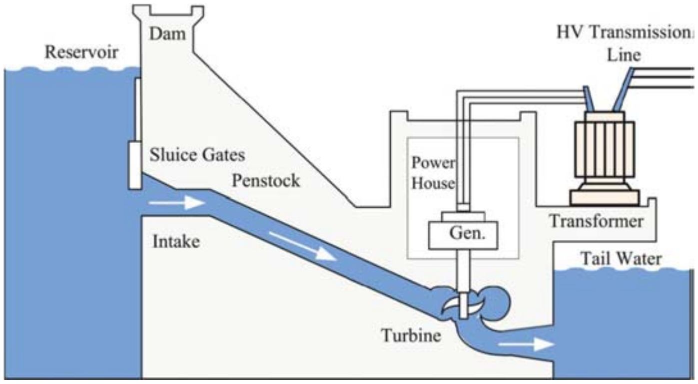


Figure 1. A schematic overview of the hydropower plant.

Hydroelectric projects often are combined with flood control and irrigation projects and therefore must involve the evaluation of the total environmental effects of the project. Furthermore, the dams often provide recreational areas with a lake and beaches. Undesirable effects include upstream flooding of river valleys, downstream water-flow reduction, impact on the area required for the lake, and the effects of long electric transmission lines from the project site to the area where the electric power is used. The environmental impacts of a hydroelectric project must be thoroughly analyzed since, after it is completed, they are essentially irreversible [28-33].

Three main types of turbine are employed in hydroelectric power stations. Propeller turbines, such as the Kaplan turbine, are employed for low heads of not more than 40–50 m and high flow rates ranging between 2 and 40 m^3/s [31]. They provide high rotor velocity for relatively low water through-flow velocities and may attain a good efficiency over a wide range of loads by blade pitch variation [1]. Francis turbines are used for higher heads (20–300 m) and medium flow rates (0.2–20 m^3/s); these turbines are radial inflow units where water enters the rotor through a set of variable-angle inlet guide vanes and flows radially inward and axially downward, with a pressure drop within the turbine wheel itself [31-36]. Pelton turbines, which are impulse units, are used for heads from 100 m up to 300 m or higher, with a very low flow rate, generally lower than 1.0 m^3/s [1]. All the static head is converted into velocity and all this energy is absorbed in the wheel so that water leaves at a very low velocity [1]. Since electric power generation at constant frequency requires constant speed, problems arise in the partial-load operating mode when shaft torque is reduced because of a reduction in electric power demand. Kaplan and Francis turbines can accept partial flow without significant loss of efficiency by varying either the rotor blade or the inlet guide vane angles. Pelton turbines can be regulated by an adjustable nozzle.

3.3. Biomass and waste

Biomass is any organic matter such as wood, crops, seaweed, animal wastes that can be used as an energy source [41]. Biomass is probably our oldest source of energy after the sun. For thousands of years, people have burned wood to heat their homes and cook their food. Biomass gets its energy from the sun [42]. All organic matter contains stored energy from the sun. During a process called photosynthesis, sunlight gives plants the energy they need to convert water and carbon dioxide into oxygen and sugars [26]. These sugars are called carbohydrates, supply plants and the animals that eat plants with energy. Foods rich in carbohydrates are a good source of energy for the human body. Biomass is a renewable energy source because its supplies are not limited [27-29].

Photosynthesis is a process in which in organic compounds, CO_2, and H_2O are converted using light energy into organic chemicals, mainly hexose carbohydrates, such as glucose, according to the following overall reaction (see Figure 2) [26, 29, 41]:

$$6\,CO_2 + 6\,H_2O + \text{light} \rightarrow C_6H_{12}O_6 + 6\,O_2 \qquad (1)$$

The photosynthesis reaction (Eq. 1) is one of the most important biochemical reactions and it occurs in all auto trophic biological organisms such as plants, algae, and some bacteria. The initial photosynthesis products are mono saccharides, such as glucose, which are subsequently converted to various compounds, including polysaccharides (starch, cellulose, and hemicellulose), lipids, proteins, and a variety of organic compounds [26]. This way photosynthesis is a first step in the food chain of heterotrophic organisms, which cannot photosynthesize and obtain carbon either from auto trophic organisms [29, 41].

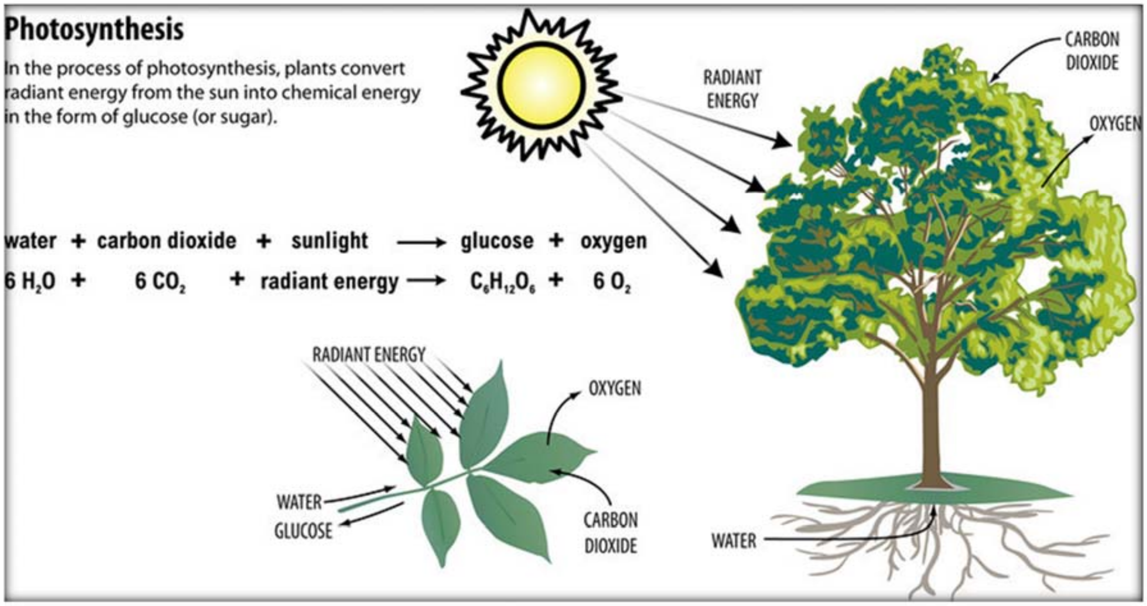


Figure 2. A schematic overview of the photosynthesis process.

Wood was used as a fuel by people for centuries prior to the introduction of coal and oil within the past 200 years. The possibility of cultivating and harvesting large forests and converting the energy to electricity is attracting interest. Forests may yield 25 to 50 metric tons/hectare per year, and the period over which these average rates are obtained ranges from 20 to 50 years. On the other hand, one concept incorporates a plan for large tree farms, covering areas from 100 to 500 million m^2, where trees are grown and harvested by means of automated methods. At the center of the tree plantation would be a wood-burning electrical power plant. The wood would be chipped in the field, then crushed to the consistency of powder before being burned [26, 28, 41].

Forests of sycamore trees may yield up to 35 metric tons/hectare per year. This is possible with new methods such as by harvesting sycamore "shoots" only two to four years old. Almost everything from trunks to twigs is used. Only the foliage is returned to the soil. Once harvested, the perennial sycamore sends out a new crop of sprouts are again ready for harvesting in two or three years. It is not necessary to replant, and little fertilizer is required. Several advantages accompany the use of wood as a fuel such as:

- Trees improve the oxygen-carbon dioxide balance in the atmosphere;
- They reduce runoff of soils and improve stream and river clarity;
- They are renewable;
- They can be grown and harvested with virtually no depletion of soil nutrients;
- The wood ash from power plants would provide a valuable fertilizer.

Urban and industrial waste can conveniently be used to produce energy in different ways. Table 2 lists typical heating values of waste [41]. Waste recovery is one of the biggest problems that private and public bodies have to tackle. Resolution of this problem is evolving slowly because of many technical, economic, and environmental constraints. Mass burning facilities where the refuse is burned as received and processed fuel where the solid waste is processed before burning are the two options that technology makes available [26].

Table 2. Typical higher heating values of waste

Description of waste	HHV (kJ/kg)
Industrial waste	
Leather scrap	23,000
Cellophane	27,750
Waxed paper	27,500
Rubber	28,500
Tires	41,850
Oil, fuel oil residue	41,850
Polyethylene	46,000
Agricultural	
Bark	11,000
Rice hulls	13,500
Corn cobs	19,000
Composite	
Municipal	10,000-15,000
Industrial	15,000-17,500
Agricultural	7,000-14,000

HHV: Higher Heating Value

Bacteria and fungi are not picky eaters. They eat dead plants and animals, causing them to rot or decay. A fungus on a rotting log is converting cellulose to sugars to feed itself. Although this process is slowed in a landfill, a substance called methane gas is still produced as the waste decays [38]. New regulations require landfills to collect methane gas for safety and environmental reasons. Methane gas is colorless and odorless, but it is not harmless [30]. The gas can cause res or explosions if it seeps into nearby homes and is ignited. Landfills can collect the CH_4 gas, purify it, and use it as fuel and can also be produced using energy from agricultural and human wastes. Biogas digesters are airtight containers or pits lined with steel or bricks. Waste put into the containers is fermented without oxygen to produce a methane-rich gas. This gas can be used to produce electricity, or for cooking and lighting [26, 29, 38].

Ethanol is an alcohol fuel made by fermenting the sugars and starches found in plants and then distilling them. Any organic material containing cellulose or sugar can be made into ethanol. The majority of the ethanol produced from corn. New technologies are producing ethanol from cellulose in woody fibers from trees, grasses, and crop residues. Today nearly all of the gasoline sold in the U.S. contains around 10% ethanol and is known as E10. In 2011, the U.S. Environmental Protection Agency (EPA) approved the introduction of E15 (15% ethanol, 85% gasoline) for use in passenger vehicles from model year 2001 and newer. Fuel containing 85% ethanol and 15% gasoline (E85) qualifies as an alternative fuel [3, 4, 26, 41].

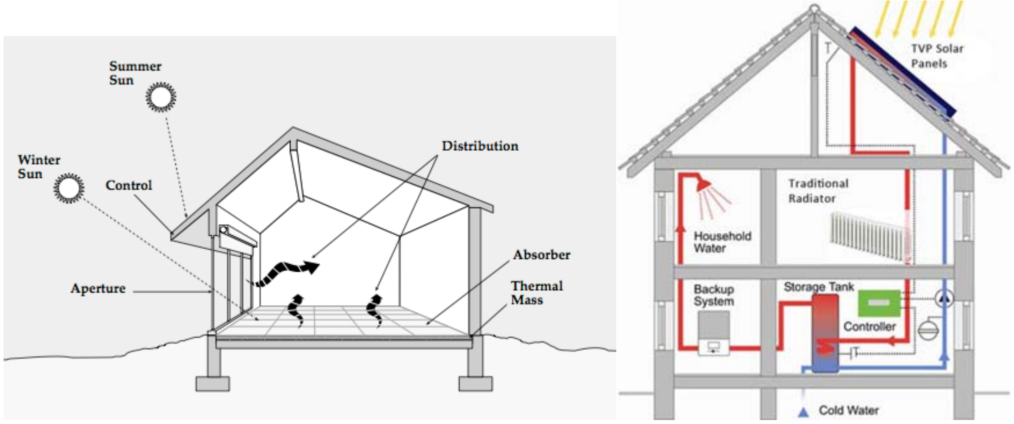
Biodiesel is a fuel made by chemically reacting alcohol with vegetable oils, animal fats, or greases, such as recycled restaurant grease. Most biodiesel today is made from soybean oil. Biodiesel is most often blended with petroleum diesel in ratios of two percent (B2), five percent (B5), or 20 percent (B20). It can also be used as pure biodiesel (B100). Biodiesel fuels are compatible with other diesel fuels and can be used in diesel engines with the existing fueling infrastructure. While removing sulfur from petroleum-based diesel results in poor lubrication, biodiesel is a superior lubricant and can reduce the friction of diesel fuel in blends of only one or two percent [2, 3, 26].

3.4. Solar energy

The solar energy reaching the earth surface can be used to produce hot water or to produce electric energy by means of photovoltaic cells. Typical values of the rate of the solar energy are 300–1,000 W/m^2 depending on the latitude, time of day, and atmospheric conditions [1]. Water can be heated by solar collectors which collect a fraction of the incident sunlight ranging between 90 and 20% depending on the number and type of glazing and on operating parameters such as rate of insulation, ambient air temperature, and input cooling fluid temperature [27]. With average values of 300–1,000 W/m^2 of solar energy rate, a standard collector may yield an actual specific power ranging from 200 to 600 W/m^2 to produce hot water at 50–60 ºC with a difference of 30 ºC between the average internal collector temperature and ambient temperature [1-3; 26-30].

Heat losses from a collector are generally defined by a coefficient (W/m^2.K) which varies from 7 with a single glazed flat plate to 2.5 in the case of a double one with selective surfaces. The solar energy, when converted into hot water or hot air, must be stored to match the end user demand throughout the day. Insulated water-storage tanks are always installed; the average capacity is at least 100 L/m^2 of collector [27]. If an intermediate fluid is used, heat exchangers with high effectiveness must be installed. With hot-air systems, thermal storage with rock bed can be used, if necessary. Generally, these systems are difficult to justify from the economic and technical points of view for use in factories and in buildings [26-30].

Buildings can be heated by passive and active solar heating systems are shown in Figure 3 [27]. A passive solar heating system absorbs and stores heat from the sun directly within a well-insulated structure without the need for pumps or fans to distribute the heat [28]. The sun's heat collected by its central greenhouse and the building's other windows is stored in the masonry, the floor, large water tanks, and the earth under the house and slowly released into the interior. This and other sources of heat, such as lights, appliances, and people, provide almost all the heat that is needed throughout most of the year for the entire building [28-37].



(a) (b)

Figure 3. Passive (a) and active (b) solar heating systems.

An active solar heating system uses energy from the sun by pumping a heat-absorbing fluid (such as water) through special collectors usually mounted on a roof or on special racks to face the sun (Figure 3, right). Some of the collected heat can be used directly. The rest can be stored in a large insulated container, filled with gravel, water, clay, or a heat-absorbing chemical, for release as needed. They can be used to heat new homes in areas with adequate sunlight. Active solar collectors using a fairly simple technology can also provide hot water. By 2030, half of all households in China are expected to be using inexpensive rooftop solar water heaters as an example of applying the solar energy principle of sustainability [1-4].

Electric energy can be produced from solar energy by using photovoltaic silicon cells. As a general indication, the voltage across one cell is 0.5 V and it is independent of the solar energy rate to which the electric current fed to the load is linearly related. In practice, cells are mounted on a module and the modules are arranged in panels or arrays in series, in parallel, or in combined series/parallel [43]. The efficiency, that is the ratio between the electric power generated and the solar energy rate, is not more than roughly 15 % for standard applications. That means that 1 m^2 of cells will produce not more than 75 W with an average solar energy rate of 500 W/m^2. The electric energy produced by a series of cells must be stored in an accumulator storage system. The equivalent operating hours at the peak power range from 1,000 to 2,000 h/years depending on the geographical location [26-30].

3.5. Wind energy

Wind energy is rightfully an indirect form of solar energy since wind is induced chiefly by the uneven heating of the earth's crust by the sun [7]. Therefore, clouds, moisture and other factors make that heating uneven. As air at different temperatures rises or falls or shifts, currents of wind result. This movement is also influenced by the climate and topography of the land. Wind seldom moves at a uniform speed, but rather swells and ebbs. Some areas generally have much higher wind than others and sometimes there is no wind at all [26].

Wind is induced chiefly by the uneven heating of the earth's crust by the sun. Thus wind energy is rightly an indirect form of solar energy. Winds can be classified as *planetary* and *local*. Planetary winds are caused by greater solar heating of the earth's surface near the equator than near the north or south poles. This causes warm tropical air to rise and flow through the upper atmosphere towards the poles and cold air from the poles to flow back to the equator nearer to the earth's surface [22]. The direction of motion of the planetary winds is affected by the rotation of the earth. Local winds are caused by differential heating of land and water, and also by hills and mountain sides. Windmills played an important role in water pumping throughout the world. Recent development of wind energy has concentrated on the electricity generation [22]. A basic relationship, which relates wind velocity to the power available and to the device surface normal to the wind velocity is given by [1]:

$$P = (1/2) \times A \times \rho \times V^3 \tag{2}$$

Where; P = power yielded by the wind source (W); A = area normal to the wind velocity (m^2); ρ = air density, and V = velocity of airstream (m/s). On the other hand, for practical applications, the ratio P/A is generally introduced as [1]:

$$(P/A) = (1/2) \times \rho \times V^3 = 0.645 \times V^3 \quad (W/m^2) \tag{3}$$

3.6. Geothermal

Over the life of the earth, thermal energy has been stored within its core. Of this energy stored within the earth, some is transmitted from the interior by means of conduction through the earth. The average rate of heat flow to the surface has been found to be 0.065 W/m^2. For the earth's surface of 510×10^{12} m^2, the total heat flow amounts to 32×10^{12} watts. Of this, only 1% of the total rate is due to heat convection by hot springs and volcanoes. Unfortunately, we cannot directly exploit this heat supply, but we can use local hot spots. It means that subterranean reservoirs where the heat has been stored in the form of steam and hot water for building and greenhouse heating. Such reservoirs are the source of geothermal energy.

Geothermal energy is generated by proven technology that converts the natural heat within the earth's crust into electricity. Geothermal power draws energy from underground reservoirs of water that have been heated by geological processes. Despite high upfront costs, geothermal plants are reliable and can be used 90% of the time. It has been estimated that global geothermal power production could increase by 70% between 2010 and 2016. The United States remains the dominant producer of geothermal energy in the world, followed by the Philippines, Mexico, Indonesia, and Italy. While geothermal energy accounts for 0.35% of total US electricity production, it accounts for 17% of the electricity generated from renewable sources. Building on a rising geothermal capacity, as of May 2007, the United States had 2,850 MW of installed geothermal energy capacity, compared with 2,228 MW in 2000. Of this amount, a majority (approximately 1,875 MW) is located in California. Although 15 countries were actively engaged in new or additional geothermal development in 2005, another 40 countries were considering geothermal plants by 2007.

3.7. Fuel cells

A fuel cell by definition is an electrical cell, which unlike storage cells can be continuously fed with a fuel so that the electrical power output is sustained indefinitely [44, 45]. They convert hydrogen, or hydrogen-containing fuels, directly into electrical energy plus heat through the electrochemical reaction of hydrogen and oxygen into water. The process is that of electrolysis in reverse [43-48].

$$\text{Overall reaction: } 2\, H_2 \text{ (gas)} + O_2 \text{ (gas)} \rightarrow 2\, H_2O + \text{energy} \tag{4}$$

Because H_2 and O_2 gases are electrochemically converted into H_2O, fuel cells have many advantages over heat engines [45]. These include: high efficiency, virtually silent operation and, if hydrogen is the fuel, there are no pollutant emissions. If the hydrogen is produced from renewable energy sources, then the electrical power produced can be truly sustainable [46]. The two principle reactions in the burning of any hydrocarbon fuel are the formation of water and carbon dioxide [47]. As the hydrogen content in a fuel increases, the formation of water becomes more significant, resulting in proportionally lower emissions of CO_2. As fuel use has developed through time, the percentage of hydrogen content in the fuels has increased. It seems a natural progression that the fuel of the future will be 100% hydrogen [43-48]. Table 3 gives three typical types of fuel cells. Fuel cells, operating on non-petroleum fuels such as hydrogen, might provide an alternative energy source for electric traction and for other applications with a total efficiency, that is, combined hydrogen and electricity production efficiency, of roughly 25–40% Figure 4 shows the structure of Solid Oxide Fuel Cells.

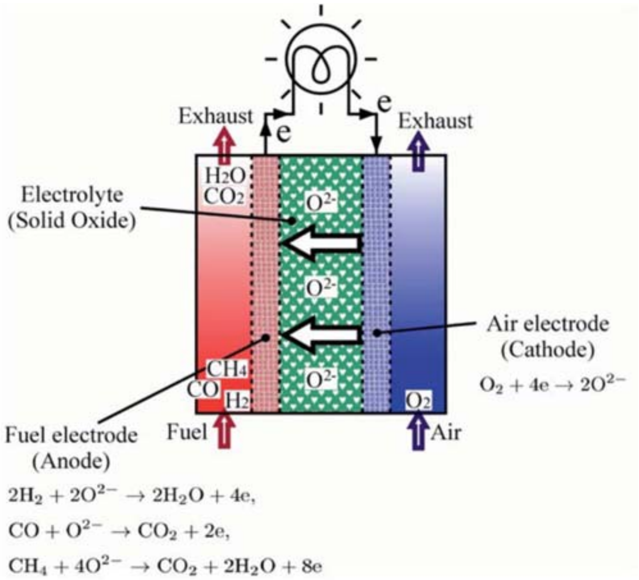


Figure 4. Structure of Solid Oxide Fuel Cell and mechanism of electricity generation.

Table 3. Three typical types of fuel cells

	Polymer Electrolyte Fuel Cell (PEFC)	Molten Carbonate Fuel Cell (MCFC)	Solid Oxide Fuel Cell (SOFC)
Temperature (ºC)	60-80	600-700	600-1000
Fuel	H_2, CH_3OH	H_2, CO	H_2, CO, C_xH_y
Electrolyte	Polymer Membrane	$Li_2CO_3 + Na_2CO_3$	YSZ, SSZ, Ceria
Conducting ion	H^+	CO_3^{-2}	O^{-2}
Oxidiser	Air	Air with CO_2	Air
Catalyst	Pt	Pt, Pt-Ru	-

4. Conclusions

Energy, the ability to accomplish physical work, comes to our attention principally as an input for economic processes and as an intermediate good. It is rare to find energy demanded for its own sake. Energy is usually valued as an input in some process of production or utilization which results in a final product. Economic development has gone hand in hand with increased energy used per capita, beginning in history with solar energy embodied in plants and animals, and continuing through draft animals, wind energy, and fossil fuels. Energy input always produces some measure of pollution, since waste products occur along with the desired goods. Energy is central to human development. It accelerates social progress and enhances productivity. Without the provision of and access to clean, reliable, and affordable energy services, other economic and social development goals cannot be achieved. Energy directly affects people, communities and countries in terms of economic growth, health, security, environment, education, and employment. The challenges associated with sustainable energy are not primarily about physical access to the electricity grid or gas distribution network. They are mostly related to the inefficient use of energy, frequent power cuts, increasing energy costs, sustainable and affordable heating in winter, and the slow uptake of renewable energy.

Green chemistry is not a new branch of science. It is a new philosophical approach that through application and extension of the principles of green chemistry can contribute to sustainable development. Presently it is easy to find in the literature many interesting examples of the use of green chemistry rules. They are applied not only in synthesis, processing and using of chemical compounds. Many new analytical methodologies are also described which are realized according to green chemistry rules. They are useful in conducting chemical processes and in evaluation of their effects on the environment.

The governments and public policy makers throughout the world are increasingly viewing renewable energy as an important component of strategies aimed at addressing the challenges associated with energy production and use. The principal challenges include the tradeoff between economic growth, environmental impacts, and national security. Driven by these combined pressures, a number of energy policies put in place around the world during the last decade have helped the renewable energy industry to grow significantly. Because most renewable energy technologies are not yet, in most regions, able to compete economically with fossil fuels, they will have to be supported by public policy interventions if renewable energy is to play a real near-term role in energy policy. Public policies are currently necessary to reduce the costs and improve the investment environment to enable significant and long-term growth in the use of renewable energy.

Renewable energy plays a key role in future low carbon-emission development aimed at limiting global warming. However, its dependence on climate conditions makes it also susceptible to climate change. In its various forms of green energy comes directly from the sun. In 2016, about 20% of global final energy consumption came from renewables, with 12% coming from traditional biomass, which is mainly used for heating, 4% from hydroelectricity and 4% from other renewables such as wind, solar and geothermal energy. The share of renewables in electricity generation is around 19%, with 15% of global electricity coming from hydroelectricity and 4% from new renewables. In recently, worldwide renewable energy capacity grew at rates of 10–60% annually creating businesses and employment. Renewable energy replaces conventional fuels in four distinct areas: power generation, hot water/space heating, transport fuels, and rural (off-grid) energy services.

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