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Emerging Energy Sources for Sustainable Power Generation: An Overview

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ABSTRACT: Electricity plays a big part in our daily life. Energy supply is a key factor in the modernization, automation, and expansion of the economy. Traditionally used energy sources are primarily used to create it. While traditional energy sources are rapidly running out, energy demand is rapidly increasing. A global problem is poor energy management as a result of scarce land resources, tight energy budgets, and weather-dependent renewable energy sources. Researchers that study energy are primarily concerned with the depletion of conventional energy and the parallel development of practical alternative energy sources. Only 20% of the country's energy is used by homes; the remaining 80% is split across different economic sectors. When it comes to achieving sustainability in power generation for sustainable development, the topic of renewable energy sources for generation cannot be overemphasized. The two main issues in the fight against climate change are without a doubt energy security and sustainability. Clean energy and a healthy environment are necessary for a world where people, plants, and animals can live in peace and health. Therefore, finding ways to incorporate renewable energy into the mix of energy production is necessary to improve energy sustainability and combat climate change. To demonstrate their current condition and potential in the future, the literature on new energy sources is explored in this article. This analysis explains policies for renewable energy, potential assessments, comparative studies, energy optimization, sustainability, and the adaptation of strategic policies to promote the development of emerging renewable energy as a source of power generation to accelerate economic growth and preserve the environment.

KEYWORDS: renewable energy sources, energy efficiency, sustainability, and climate change

1 INTRODUCTION

Due to the increasing daily need for energy by all people on the planet, which the earth's structure cannot change, the world is quickly becoming a global town. The need for energy and related services to support human social and economic development, government aid, and well-being is growing. All social systems depend on the management of energy to provide basic human needs including comfort, lighting, food, space solace, adaptability, and communication while functioning as generative cycles. The two key challenges for energy that are preventing a course for a sustainable future are securing the energy supply and limiting energy commitment to environmental change (Sarkodie, 2016). Renewable energy sources might potentially replace themselves spontaneously without depleting the soil, according to (Owusu et al., 2016). Examples include ocean energy (tidal and wave), hydro, solar, biomass, and wind. The inclusion of renewable energy sources in the generating mix has resulted in a notable decrease in greenhouse gas emissions, which has gradually mitigated climate change. It has also resulted in a decrease in environmental and health problems brought on by pollutants from fossil fuel energy sources. The adoption of appropriate renewable energy technology and policies resulted in an average reduction of 14% in greenhouse gas (GHG) emissions per capita across 33 European Environmental Agency (EEA) nations between 1990 and 2021.

According to (Salvarli et al., 2020), the switch to renewable energies reduces environmental expenses, enabling the energy system to run proficiently and extremely affordably without facing environmental problems. To maximize the effectiveness of an innovative technology aimed at the problem or challenge identification, as well as the preferences of the renewable energy source, certain parameters must be put in place. As a result of the industrial revolution that occurred in the 18th century, which resulted in a complete change from the use of humans and animals for labor to the employment of cutting-edge technology and machines for increased efficiency, Ghana and the rest of the world now view the availability of energy as the primary force behind all industrialized states. Fossil fuels are thus used to power industries, which improves household activities while providing essential services.

Research has shown that the reliance on and limited nature of the fossil source of energy over the years has social inequality with its associated negative environmental impact on the environment climates. In recent times, the energy demand exposes the limitation of the fossil energy source in terms of sustainability. (Antwi, 2020)

According to (Mohammad et al, 2021), there is a worldwide energy change happening. The article also supports natural gas as a substitute source, arguing that it is a suitable primary energy source for the switch to sustainable renewable energy sources over the short- and medium-term. In addition, a range of methods and renewable energy sources can be used to produce natural gas. Due to their adaptability, natural gas power plants can absorb occasional renewable energy sources like the sun and wind. The CO_2 emissions brought on by the generation of electricity from natural gas could be reduced by utilizing cutting-edge natural gas conversion technology, including renewable energy sources, and CCS technologies.

(Wo'zniak et al, 2022) notes that by 2050, all predictions suggest that the economy, transportation, and industry may rely virtually totally on renewable energy sources. The potential for adopting emerging renewable energy sources is rising. A sustainable energy and climate plan should aim to achieve three equal goals, which will make for the best summary: competitiveness, sustainable development, and supply security.

(Fazlur et al, 2022) looks at how careful planning and optimization can help one make the most of these new energy sources. A variety of less common energy sources, including nuclear, hydroelectric, heat, chemical, biological, mechanical, and waste from various sources, seem to have promise for the creation of sustainable power. To ensure general acceptance, particular considerations must be taken, such as combining conventional and renewable energy sources while generating electricity. Combining these future energy sources is feasible and sustainable because of recent advancements in energy hybridization.

(Zahedi et al., 2022) claim that the efficiency of renewable energy sources varies from nation to nation and is also reliant on the policies and technology put in place. Because of its economic competition on the market, hydro, for instance, is widely chosen and given precedence in the renewable energy family in a country like Ghana, whereas solar, biomass, and wind are primarily employed for off-grid applications.

According to the BP energy outlook released in 2018, the use of renewable energy sources will reach 14% of the world's primary energy.

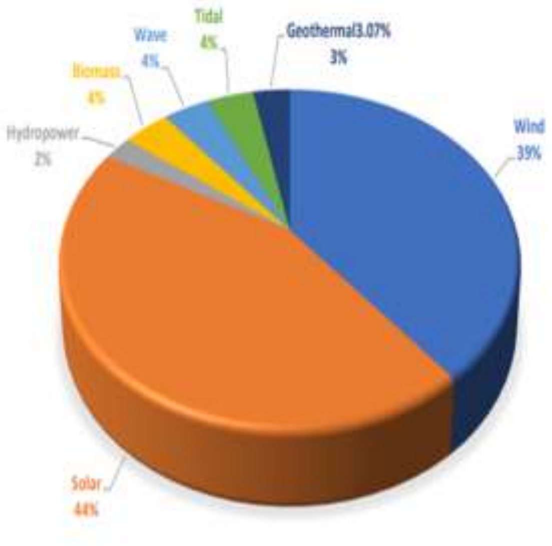

Fig 1. Distribution of renewable energy generation and its global utilization

A lot of money was invested in the global development of new energy sources between 2011 and 2020, including geothermal energy (4%), solar energy (15%), wind energy (27%), biomass energy (43%), and small hydro (9%).

(Vedanarayanan et al, 2022) investigations reveal that, in today's energy generating and distribution business, the phrase "smart grid" is frequently used. The smart grid, when combined with distributed power generation, creates a new platform that dramatically improves electric energy security and quality. A smart grid can change the electrical grid of the twentieth century into a network that is more intelligent, adaptable, dependable, self-balancing, and interactive, allowing for economic development, monitoring, energy security, and operational efficiency.

According to Krishna et al. (2022), studies have increased their focus in recent years on assessing the negative effects of global temperature change or the unchecked expansion of ozone-harming compounds on our daily routines. This man-made condition has had a significant negative influence on the environment, substantially affecting human well-being and economic growth. Primarily, the findings made it abundantly clear that ecological conditions, food production, and access to water are the areas that are primarily seriously damaged, which has in the past resulted in some harm. It makes sense for things to go worse in the upcoming times.

(Said et al, 2022) mentions that all through late years, there has been a flood in research on the legitimate turn of events. Energy is normal for monetary augmentation, and harmless whiles the ecosystem power sources are normal for affordable development. Yet the world has in recent times seen a speedy improvement, with harmless to the ecosystem power maintenance levels showing up at twofold digit degrees across a couple of countries' power age, various other non-modern nations are presently at a beginning level in harmless to the ecosystem power age. Additionally, non-harmless to the ecosystem power has remained the most extensively utilized power source in the causing situation, addressed in the abundance of 87% of energy essentials. Oil-based goods and other non-harmless to ecosystem power sources make CO_2 surges accordingly.

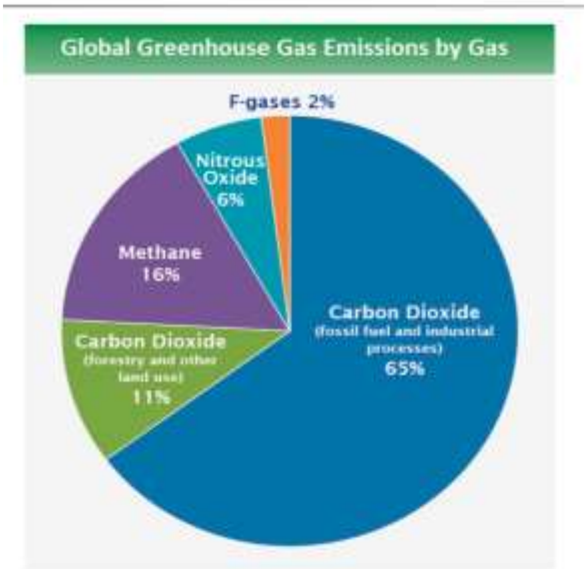

Fig. 2 depicts the global greenhouse emissions by gases

According to (Kabeyi et al, 2022) fossil fuels, particularly coal, natural gas, and oil, contributed 61.3% of the world's electricity production in the year 2020, making them the greatest sustainability challenge facing humanity at the time. Fig. 2 provides a graphical representation of the percentage of gas emissions worldwide in line with the energy source as of the same year.

Sustainability in global development (SGD) was acknowledged as a key component of the Stockholm, Rio, and Johannesburg conferences' overall outcomes. For maximum use of the abundant but intermittent renewable sources, a sustainable mix with limited non-renewable sources, and new technology that uses conventional mitigation, negative emissions, and technologies that capture and sequester carbon emissions are required. These technologies must be optimized to minimize cost and environmental impact while maintaining the quality, stability, and flexibility of an electricity supply system.

2 METHODOLOGY

Numerous ways to generate electricity already exist, but they are currently receiving little attention, according to (Fazlur et al, 2022). In the section that follows, several potential near-future sources and associated processes for generating power are discussed;

2.1 Mechanical Sources

Kinetic energy and potential energy are the two main types of mechanical energy. Below are some less common mechanical energy sources that could serve as a source of electricity.

2.2 Smart-Energy Textiles

Power can be generated by triboelectric generators and used in smart energy textiles (TG). These sources create small-scale power. Although there are many TG variations, the textile variety stands out. Through the use of human motion and an attachment to woven fabrics, electricity can be generated.

Both negative and positive charges are produced when a force is applied to the surface of the split silk fiber and TG contact. As the mechanical force is removed, the distance between the two fiber surfaces increases the most. The surfaces could vary from one another. The electrons will eventually move from the electrode to the silk thread, as seen in Fig. 3. According to Wang et al., a fabric with a surface area of 48 cm2 generated 105 V open-circuit voltage and approximately 6 A of closed-circuit current at a frequency of 1 Hz.

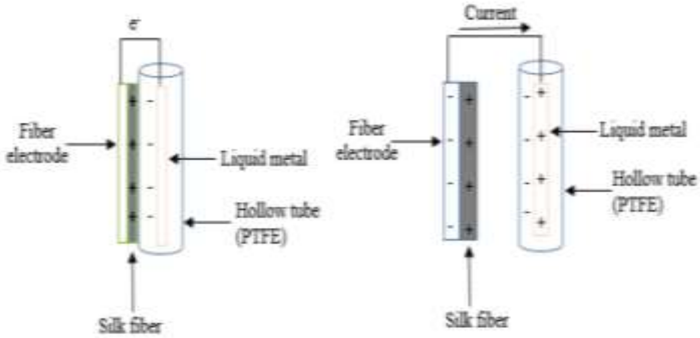

Fig.3 Schematic diagram of stages of electricity generation using smart energy textiles

2.2.1 Speed Breaker

A speed breaker is an essential part of roads and highways. The large mechanical stress placed on the speed breaker can be converted into electricity using the technique shown in Fig. 4. Many processes lose a considerable quantity of energy.

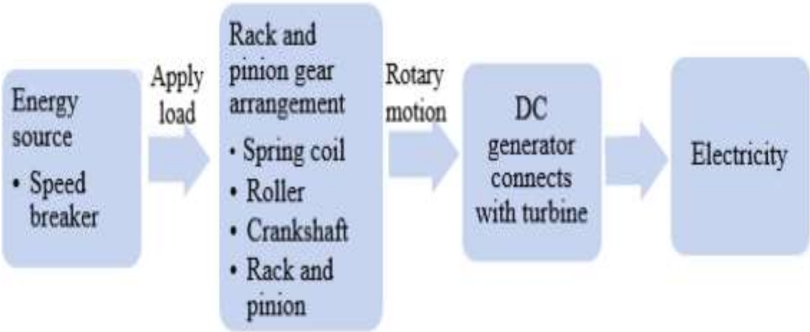

Fig. 4 Production of electricity from the speed breaker mechanism

Around the world, a lot of energy is lost at various speed bumps. With the aid of several tools, like a rack and pinion gear, modern technology can transform this squandered energy into electricity. To remove these mechanical energies as a vehicle passes over it, the speed breaker is often fitted with a spring or roller mechanism. Electricity is exclusively produced and operated by the rotational motions of the dc generator. A running vehicle with a weight of 400 kg and moving at a speed of 50 km/h generates a maximum voltage of 14.91 V and a mean power of 11.21 W, according to Santhosh et al. Several mechanisms, such as a spring coil, roller, crank, and the speed breaker itself, are employed to create energy. A vehicle suspension system's linear motion and vibration can be used to generate mechanical energy, which can then be transformed into electrical energy. Mechanical Energy Nanogenerators

A nanogenerator is a type of technology that converts thermal and mechanical energy into electricity by making extremely small physical changes. There are three different ways to use nanogenerators to generate energy, including

Pyroelectric, turboelectric, and piezoelectric materials are used to create nanogenerators. During the functioning of nanogenerators, a vertical nanowire is subjected to a tip that must be moved laterally, and the tip is then moved to apply an external force. The tip end of the nanowire generates an electrical voltage that is spread out over the surface. On the other side, the bottom end of the nanowire neutralizes because it is anchored to the ground. According to estimations, a nanogenerator constructed of a material similar to KnbO3 might generate 16 V of output voltage, whereas one made of ZnO could generate 9 mV.

2.2.2 Electricity from the Motion of People

A typical person uses about 280 kcal per hour—roughly 324 W of power—during routine activities like walking, which can be used to generate electricity. This energy can be absorbed and converted into electric energy using a variety of systems of procedures, including certain kinds of tiles. Similarly to this, carrying a backpack while walking can produce kinetic energy that could be converted into electricity.

In a fascinating study using the "Green Wheel" to test laptop charging, Shepertycky, and Li. They found that using energy from the Green wheel, a typical laptop with a 120 W capacity could be fully charged in 2 hours. It is possible to turn a soccer ball into a small power bank that may be used to run chargers for phones and lights. Idoni-Matthews et al. claim that an hour-long soccer match produces the same amount of electricity (2–17 W).

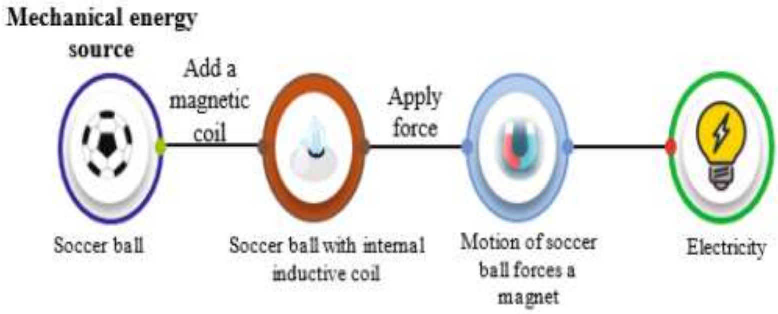

Fig. 5 Electricity generation from soccer ball motion

2.3 Additional Uses for Solar Energy

Numerous ways in which solar energy enhances our daily life. The two most popular methods for using solar energy to make electricity are using PV cells and using heat. The section that follows has highlighted a few of the less appealing aspects of harnessing solar energy to generate electricity.

2.3.1 Thermal Electrochemical Converter

In normal heat and power systems, the thermal demand for heat is satisfied by standard fuels like diesel, gasoline, and so forth. Instead of using fossil fuels, solar energy is a fresh and useful future alternative that can be used to achieve this. Solar energy has the potential to reduce pollution from burning fossil fuels while producing heat and electricity. The thermal electrochemical converter is a potential way to create electricity (TECC). Heat energy is used to produce electricity in a sodium TECC, where sodium ions (Na+) are expanded isothermally and transmitted through an electrolyte of beta-alumina as shown in the figure below.

2.3.2 Electricity from the Production of Synthetic Gas or Liquid Fuel

Solar energy can be utilized to create synthetic gas that is primarily composed of carbon monoxide (CO), hydrogen (H2), and very little carbon dioxide (CO2) (CO2). This synthetic gas can be used to create fuels such as gasoline, kerosene, and others.

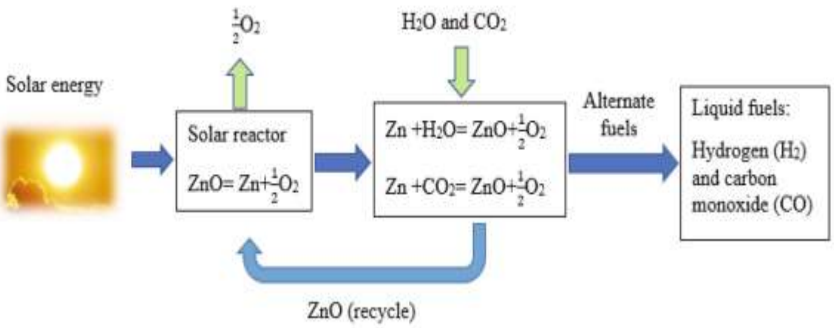

Fig. 6 Solar energy utilizes to generate synthetic gas

Carbon dioxide (CO2) and water, two common combustion byproducts, are reenergized using solar energy (H2O). The need for fossil fuels decreases as a result, as do waste production and environmental harm. The use of solar energy's thermochemistry results in endothermic processes, as seen in Fig. 6. where chemical fuels like hydrogen and carbon monoxide are used to store solar energy (H2). Hydrogen (H2) must be separated from oxygen (O) and carbon (C) from oxygen (O2) when water (H2O) and carbon dioxide (CO2) are heated to temperatures above 2500 K.

Between 1100 and 1800 °C, redox reactions first remove the oxygen from the metal oxide. The metal is then treated with water or carbon dioxide to react with it at a lower temperature of 300–900°C, as seen in the above Figure. The metal oxide most frequently used in the production of synthetic gas is zinc oxide. Recycling this zinc oxide (ZnO) can increase gas production capacity while costing less. In dry or difficult terrain, electricity can also be produced using this method.

2.3.3 Solar Window and Door

As an alternative to standard materials for doors and windows, semi-transparent double-glazed materials with built-in solar photovoltaic cells may be utilized. Buildings that have such components in their doors and windows can produce a lot of electricity. A key indicator of the effectiveness of this solar window mechanism is the cooling requirements of residential and commercial structures. To power, a family of 2 to 5 people, an estimated solar transmittance of 40% through a solar window-to-wall ratio of 50% produces around 2 to 7 W of electricity. Additionally, the use of solar photovoltaic windows and doors can cut grid electricity consumption by roughly 55%.

2.3.4 Space-Based Solar Power

However, solar power harvesting systems, which can be deployed in satellite-based facilities, seem to be an ambitious strategy for generating electricity at the time. The distribution pattern of solar radiation makes it abundantly evident that the sun's strength is greater in space than it is on the surface of the earth. Significant amounts of solar radiation's energy could be converted into other forms of energy, such as heat and electricity, via a solar-powered system. This generated electricity can be wirelessly transmitted to the receiver. A large solar power retrieving system deployed on a satellite with a long transmission system, in Landis' estimation, can generate 1 to 10 MW of electricity. It is conceivable to use solar-powered energy given from a system in space.

2.4 Biological Sources

Plants and other biological materials are used today to produce energy in a variety of ways.

Table 1.Breakdown of electrical abilities of Biological species in watt (W)

Biological and plant sources	Process of electricity generation	Generated capacity	References
Jellyfish	Using photovoltaic device (PV)	600 V	84
Tomato	Microbial electrochemical cell	0.3 W	100
Algae	Bio-photovoltaic cell	0.5 W	105
Lemon	Electro-chemical reaction	0.000216 W	93,94
Bryophyllum leaf	Electro-chemical reaction	0.002952 W	101
Potato	Microbial fuel cell	334.1 mW	97
Orange and limes	Electro-chemical reaction	0.0003 W	93,94
Pickled foods and vegetables	By soaking in brine	110 V	97

These renewable biomaterials can be used to generate electricity. It is possible to use molecules from biomaterials, such as proteins and peptides, as potential sources of energy to create electricity. The table that displays the electrical potential in watts of several biological species is shown in Fig. 7.

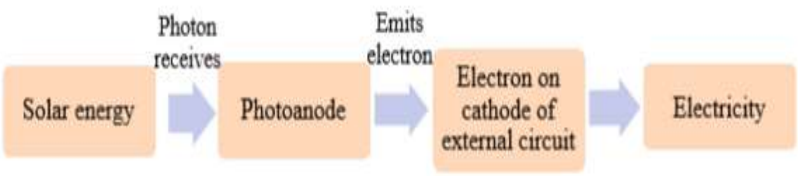

Fig. 8 Electricity generation from solar energy using photo electro catalytic cell

2.4.1 Fish and Aquatic Plants

Different energy-producing substances found in living things can transform into a kind of useful energy. Figure 8 depicts the methods for harnessing the power of diverse biological organisms, including jellyfish and algae.

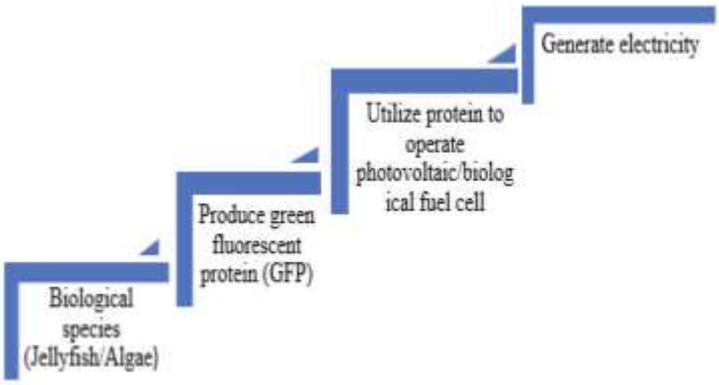

Fig. 9 Electricity generation methodology from biological species

Jellyfish

It is commonly known that jellyfish can destroy natural habitats. The opening and shutting of the bell determine the peculiar movement of jellyfish. Several ring muscles can be seen around the bell borders of jellyfish. Compression forces are created inside the ball edge when the muscles are engaged. But the rotation of the vortex rings inside the bell edges is what generates thrust. During the contraction phase, the muscles and bell edges of jellyfish enlarge. These patterns of jellyfish movement all indicate the earliest steps of developing high electric potential.

Aquatic plants and algae

Algae powered by a variety of photosynthetic microorganisms are used to power bio photovoltaic devices in an ocean wave. In this method, a layer of photosynthetic cells is deposited on top of a transparent conducting electrode so that they face a platinum nanoparticle-coated carbon cathode. When sunlight strikes an algal cell, it begins to divide the water, releasing protons, oxygen, and—most importantly—electrons. Electric cells will eventually allow for the recovery of electricity.

2.5 New Materials for Nuclear Power Plants

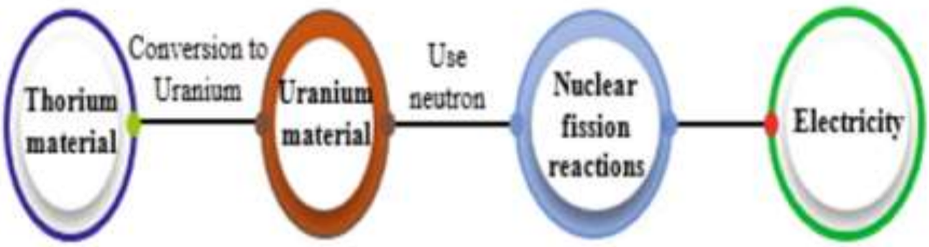

Fig. 10 Electricity generation methodology from nuclear sources

Nuclear energy sources provide power without emitting carbon-related pollution by using nuclear fusion and nuclear fission reactions. Along with other typical radioactive elements, thorium can be used to generate electricity. Thorium can be used to create uranium in a liquid fluoride thorium reactor. The conventional nuclear power plant approach can be used to turn this manufactured uranium material into electricity, as shown in Fig. 10.

Like other radioactive materials, thorium generates harmful gamma rays with an energy of roughly 2.6 MeV.

2.6 Unusual Ways of Utilizing Waste

Different wastes contribute to environmental contamination in various ways. The management of this waste in conjunction with energy conversion is currently one of the most important study fields. Two methods of converting garbage into energy are pyrolysis and gasification. Converting garbage into power can greatly lessen the requirement for electricity while simultaneously lowering waste-related pollution.

2.6.1 Organic Waste

Household garbage is transformed into energy by anaerobic digestion, which produces biogas from domestic organic waste. Anaerobic digestion is a technique used to dispose of household organic waste in landfills or compost. Organic waste is then processed through anaerobic digestion to create biogas, which has a CH4 level between 55 and 65 percent and a carbon dioxide content between 35 and 45 percent. Additional biogas can be produced via anaerobic digestion and used to generate electricity. The degradation of organic waste happens in three stages, as depicted in Fig. 12. First, Organic waste degradation happens in three stages. First, hydrolysis techniques are used to convert insoluble materials into soluble monomers. Then, via the acid production process, the soluble monomers are transformed into volatile fatty acids. Finally, utilizing the methane creation method, the volatile fatty acids are transformed into biogas, which generates electricity

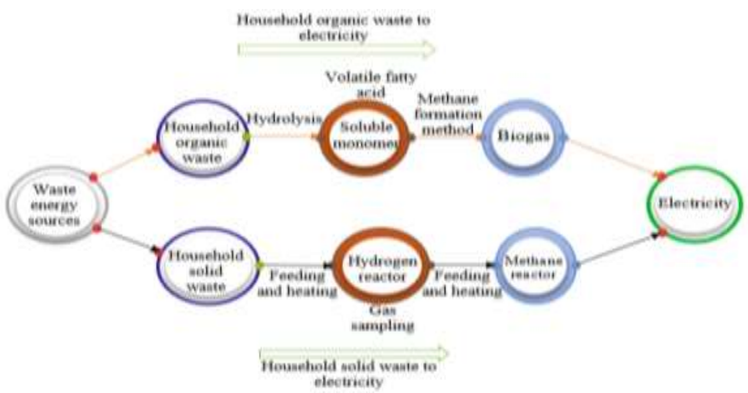

Fig. 12 Electricity generation methodology from household organic and solid waste

2.6.2 Residential Solid Waste

Household solid waste is a possible source of energy for generating hydrogen (H2) gas for electricity production. The dark fermentation technique is one of several generally available technologies for generating hydrogen gas from domestic solid waste.

About 37 C H2/g of hydrogen is produced by the hydrogen reactor, and this level must be kept in both the hydrogen and methane gas reactors. The second phase involves feeding hydrogen gas through an effluent bottle into a methane reactor, where it finally creates methane that is later transformed into energy. Managing electronic trash is a major challenge today. There are numerous methods for managing this e-waste, including energy conversion and recycling. E-waste may be used to produce electricity.

2.6.3 Wastewater

Wastewater can be used to create fertilizer and plant nutrients. Wastewater is also one of the less popular sources used in the creation of power. Hoque et al. looked at using micro turbines positioned over the flow conduit to turn stored household wastewater into electricity. Once more, the anaerobic wastewater and sludge treatment digestion process is used to recover a significant quantity of energy from domestic wastewater and dissolved organic components. According to Biswas et alstudy.'s for Bangladesh, household sewage and wastewater produced 58 MW/day of electricity in 2013.

2.7 Chemical Sources

When chemical bonds are made or destroyed, energy is either absorbed or released. The components involved in a chemical reaction determine how much energy is produced or absorbed during the process. This section presents a list of unique chemical energy sources that can be utilized to produce electricity, including:

2.7.1 Bio-Batteries

A bio-battery is a type of energy storage that uses organic molecules to produce electricity. Blood glucose is an example of a typical organic substance that can be used to power electrical appliances. In the human body, enzymes normally create electrons and protons after converting them o glucose.

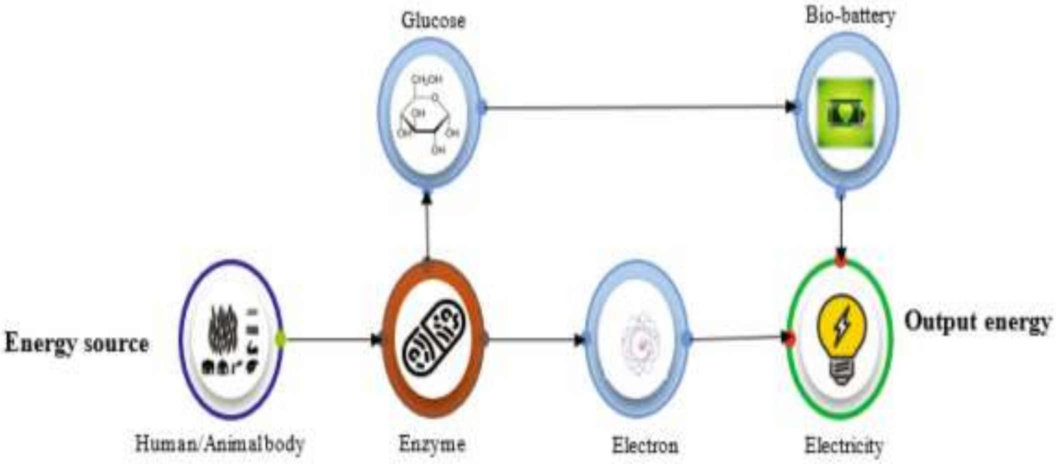

Fig. 13 Electricity generation methodology from bio-battery

As shown in Fig. 13, enzymes can be used to produce glucose, which is directly used to produce electricity in bio batteries. Similar to how energy is produced by plants and animals, bio batteries might be used to generate electricity. Siddiqui and Pathrikar claim that a single bio-battery could power a 15-cell graphite stack for 5 W. Zhu et al. (2018) stated that using 13 different types of enzymes and fresh air, they were able to produce one glucose unit for 24 electrons. This is equivalent to a bio-power battery's output of 0.8 mW/cm2.

3 CONCLUSION

Reliable energy is necessary for human progress directed toward rapid economic growth and productivity to achieve an endlessly attractive life. Experts have discovered that a nation's entire course of events depends heavily on environmentally safe electricity sources. Therefore, it is necessary to continue learning about the methodology for integrating renewable energy sources into the energy mix until complete eradication of the problems caused by climate change is achieved. The economy, mechanical manufacturing, construction, transportation, and other sectors that underpin job growth would all benefit from improved energy security.

Utilizing solar, wind, and biomass energy sources to meet local energy needs will improve environmental protection. Therefore, integrating renewable energy sources into the mix of power generation should be viewed as an artistic expression of the need to protect the environment and human needs. To speed development in these sectors, developing nations like Ghana must move investment away from non-renewable energy sources like fossil fuels and toward more sustainable renewable energy sources like solar, wind, tidal, geothermal, and biomass.

Solar, wind, small hydropower, heat recovery, and biomass makeup 44%, 40%, 13%, 2%, and 1%, respectively, of Iran's renewable energy sources. This has allowed for the direct or indirect employment of thousands of people.

Ultimately, energy is produced from the developing sources utilizing simple hand-held techniques that may run devices like electric watches, mobile phones, computers, home lighting, and streetlights. The electrical grid of the twenty-first century could be replaced by a smart grid, which would provide a network that is more intelligent, flexible, reliable, self-balancing, and interactive, enabling economic growth, monitoring, energy security, and operational efficiency. Power can now be generated simultaneously from both common and unusual sources thanks to integrated systems that modern technology and research have produced. The results of this review have numerous significant ramifications for practice going forward. To determine the sustainability of the proposed methodologies in power generation, more experimental research on these methods is required.

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