Chapter

Renewable Energy and Green Technology

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Abstract

Our present need is to reduce or minimize the dependency on fossil fuels through a thorough understanding of the principles and utility of renewable energy along with green technology. It has been considered that renewable energy as an alternate source is the best and cheapest source of energy. The unwarranted usage of fossil fuels has a huge effect on climate change globally. This can be restored by the efficient utilization of renewable energy resources. Efficient utilization of renewable energy resources could minimize the impact of climate change globally. Generally, renewable energy is generated from essentially inexhaustible sources, including wind power, solar power, geothermal energy, tidal energy, biomass energy, and other sources. Sustainability researchers have highlighted the importance of green energy and its immediate impact on the environment. Therefore, transitioning toward green energy is crucial to reducing the global crisis and achieving sustainable development.

Keywords: green energy, sustainability, fossil fuels, renewable resources, green technology

1. Introduction

Since early ages, the Earth has depended on various forms of energy for its survival. From the initial age of the Industrial Revolution, fossil fuels have been used to generate energy for the needs of our daily lives. The first use of fossil fuels for energy production dates back to the early 1800s when coal was used to power steam engines. As the demand for energy increased globally during the Industrial Revolution, there was a need to create an alternative option besides fossil fuel to generate electricity and this was followed by the development of oil and natural gas as sources of energy in the late 1800s and 1900s.

The field of green chemistry has been attracting scientists and researchers for decades. Green chemistry is an innovative technology that reduces environmental damage and waste generated during chemical processes. It has introduced new terms such as “eco-efficiency,” “sustainable chemistry,” “atom efficiency,” “process intensification and integration,” “inherent safety,” “product life cycle analysis,” “ionic liquids,” “alternate feedstocks,” and “renewable energy sources.” Its sixth principle offers a new approach for modifying known synthetic reactions in a sustainable manner. This involves replacing organic solvents with non-organic media to eliminate the volatility and corrosiveness of hazardous solvents, which helps to preserve the environment. The 12 principles of green chemistry are widely accepted criteria for comparing the environmental acceptability of these two processes. However, these principles do not fully explain the concept of green chemistry, which includes monitoring the lifecycle of fundamental processes and products, as well as recovering heat from exothermic or endothermic reactions [1].

In recent years, the use of fossil fuels such as oil and natural gas for energy production has increased dramatically, leading to widespread dependence on non-renewable energy sources. Unfortunately, this trend has also resulted in significant environmental consequences. To combat this, a transition toward low-carbon solutions is essential to reduce energy-related carbon dioxide (CO2) emissions, which make up two-thirds of all greenhouse gases (GHG). This transition can be made possible through technological innovation, particularly in the field of renewable energy. Thanks to rapidly falling costs and competitiveness, renewable energy sources such as solar photovoltaics (PV) and wind power have seen record new installations. One-quarter of all electricity worldwide was produced from renewables in the year 2017. However, the transition is not happening fast enough: After 3 years of steady CO_2 energy emissions from 2014 to 2016, they rose by 1.4% in 2017 [1].

Nowadays, about 45% of the total amount of carbon dioxide in the air comes from the burning of fossil fuels. It also releases other greenhouse gases like methane and water vapor which trap the heat coming from the Sun leading to "global warming." The burning of fossil fuels also releases a range of harmful pollutants, such as sulfur dioxide (SO_2), nitrogen oxides (NOx), and particulate matter into the air. This leads to air pollution, which has been linked to respiratory and other idiopathic diseases. Fossil fuels are finite resources and their continued use without alternative energy sources will lead to their depletion. This could lead to energy shortages, price spikes, and geopolitical tensions as countries compete for limited resources [2].

2. Concept of green energy

The word "renewable" means, capable of being renewed. Renewable energy is the type of energy that is produced from sources that are naturally replenishing and do not deplete over time such as solar energy, wind energy, hydroenergy, and so forth. Green energy is that which comes from natural sources, such as the sun, wind, water, tides, geothermal heat, or algae.

Though there are some differences between green energy and renewable energy, in most cases, they are considered just the same. In all likelihood solar energy, wind energy, hydrothermal energy, geothermal energy, vibrational energy, and biomass energy all are green as well as renewable. The concept of green energy is based on the principles of sustainable development, which aim to meet the needs of the present generation without compromising the ability of future generations to meet their own needs.

Green energy has become increasingly popular in recent years as more individuals, businesses, and governments recognize the importance of sustainability and environmental responsibility. Many countries have set ambitious targets for renewable energy adoption, and some have even committed to reaching net-zero emissions in the coming decades. While there are still challenges to overcome in the adoption of green energy, such as the need for energy storage solutions and infrastructure upgrades, the benefits are clear. By transitioning to renewable energy sources, we can create a more sustainable and resilient energy system that benefits both current and future generations [3, 4].

3. The need for green energy

Green energy is becoming increasingly important as the world becomes more aware of the negative impact of fossil fuels on the environment and the need to reduce carbon emissions. One of the key benefits of green energy is its ability to reduce greenhouse gas emissions. Burning fossil fuels contributes to both global warming and climate change. Renewable energy sources such as wind, solar, and hydropower produce little or no emissions, helping to mitigate the effects of climate change. Green energy is also a key driver of economic growth and job creation. The renewable energy industry employs millions of people around the world, from engineers and scientists to construction workers and installers. As countries invest in renewable energy, they are also creating new markets for products and services related to clean energy, which can boost local economies.

Another important benefit of green energy is its ability to increase energy security. Countries that rely heavily on imported fossil fuels are vulnerable to price fluctuations and supply disruptions. In contrast, renewable energy sources are typically domestic and distributed, making them more resilient and less vulnerable to geopolitical instability. Renewable energy can also improve access to electricity in remote and rural areas. Many developing countries lack access to reliable energy sources, which can limit economic development and social progress. Renewable energy technologies such as solar panels and wind turbines can be deployed in these areas to provide clean, reliable, and affordable energy.

In addition, green energy can help to conserve natural resources and protect the environment. Fossil fuels are a finite resource, and their extraction and use can have significant environmental impacts, such as oil spills and land degradation. Renewable energy, on the other hand, is derived from sources that are replenished naturally and can be sustainably managed. Finally, green energy can help to promote social and environmental justice. The negative impacts of climate change and environmental degradation are often felt most acutely by marginalized and vulnerable communities. Investing in renewable energy can help to reduce these impacts and create a more equitable and sustainable future for all.

To conclude, as countries around the world are going to transition to a low-carbon future, renewable energy will play a key role in building a more sustainable and resilient world [3].

4. Solar energy

The sun is the only source of energy for all living beings on Earth. Photovoltaic cells work on the principle that solar energy energizes the electrons in the valence band and they are transferred to the conduction band. These electrons are then available for the conduction of electricity. Solar energy can be converted into useful energy for our daily uses directly using various available technologies. These technologies are grouped under a few fundamental categories.

4.1 Solar photovoltaic (PV)

The conversion of solar energy into electrical energy is a relatively newer concept. This was successfully attempted in the year 1975 through the making of photovoltaic cells. These solar photovoltaic cells use solar energy from the sun in order to create electricity *via* the photoelectric effect. These photovoltaic cells have the power to directly convert solar energy into electrical energy. Photovoltaic cells are interconnected with each other to form a photovoltaic module. Photovoltaic modules are the basic structural and functional units of a photovoltaic system. These modules are often connected in series or in parallel in order to get the maximum energy that can be harvested from solar energy. The parallel connections are responsible for raising the energy in the photovoltaic array, while the series connections are used to increase the voltage of the photovoltaic array. These photovoltaic modules often have sizes ranging from 50w to 180w. In direct sunlight, the output goes to a maximum of 180 W. Researchers are looking to increase this number to as much as possible. The higher the total surface area of the photovoltaic cells will be, the higher will be the amount of electrical energy produced for the same intensity of direct sunlight. These modules are connected together in order to form a photovoltaic system and their circuits are usually environmentally protected by lamination [3, 5].

The photovoltaic modules form an integral part of PV systems, as they are positioned in such a way as to enable utilization for various applications. While the main cost of the system is linked to the photovoltaic array, the other components and the overall balance of the system are the main factors determining the reliability, efficiency, and safety of the installation that uses the photovoltaic modules. The sunlight is converted into direct current, and this direct current is then converted into alternating current and adjusted to meet the power requirements of the users as they need. Although photovoltaic cells cannot directly convert solar energy into alternating current, the direct current that is produced has its own functionality. If required the direct current can be converted into alternating current by the use of generators and then be used as per the requirements [5, 6].

4.2 Solar thermal

In the solar thermal process, we produce electrical energy by using the heat energy of the sun radiated through IR radiations. Firstly, solar collectors can be used to absorb solar radiation in order to provide heating of water or space at lower temperatures. Parabolic mirrors can be utilized to concentrate solar radiation on a larger scale, generating higher temperatures. When solar thermal power plants are employed, this solar radiation is focused on a small area to produce high-temperature steam, which is then directed to a turbine generator. This causes the generator to rotate, creating electrical energy. This type of solar energy conversion is mainly used in commercial applications, such as factories [3].

Solar thermal energy can be categorized into two types namely

a. Parabolic trough system

b. Solar tower system

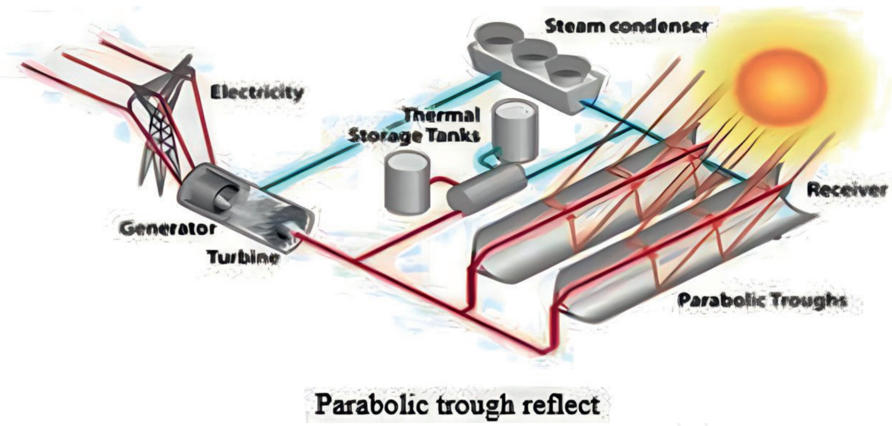

Figure 1.
Parabolic trough system - a parabolic trough system captures sunlight using curved mirrors to heat a fluid in receiver tubes. The heated fluid generates electricity via a turbine or provides heat directly for industrial uses, offering an efficient solar energy solution. (adapted from: https://www.energy.gov/eere/solar/linear-concentrator-system-concentrating-solar-thermal-power-basics).

5. Parabolic trough system

The parabolic system uses mirrors that are parabolic troughs in shape to focus sunlight on a receiver tube. This receiver tube carries a heat transfer fluid, generally, oil or water and this fluid is then heated up and pumped through heat exchangers to produce steam. The liquid can be heated up to as much as 423 K to 623 K as it flows through the receiver and it is then used as a heat source for a power generating system. This heat is then used to run turbine generators to produce electricity *via* the use of a dynamo. In this method, the water or the oil that is used can be reused after cooling them down to a certain extent. This is one of the most economical ways of solar energy conversion. This parabolic trough technology is currently the most proven solar thermal electric technology (**Figure 1**) [3, 7].

6. Solar tower system

Tower systems generally comprise three elements: ground heliostats, a tower, and a central receiver atop the tower. The heliostats capture solar radiation from the sun and direct it to the central receiver. Heliostats rotate in two directions, from east to west and north to south.

Each heliostat is programmed by a computer to follow the sun in order to maximize the total power output. This ensures that the tower traps the maximum amount of solar energy that is available at that point. The first commercial solar tower was built by Abengoa Solar of Spain. It is referred to as PS10 at the Solucar platform in the Spanish province of Seville. It was first inaugurated by the company Abengoa in order to push the production of solar electricity in Spain. The Solucar solar farm currently produces solar electrical energy of almost 3.65 GW. The Solucar solar farm comes second in order of solar production in the world just after Germany. The operation was first started in the month of March 2007 and the process is still under development by the authorities. The Solucar solar farm is the inspiration for multiple similar solar farms all over the world (**Figure 2**) [3, 7].

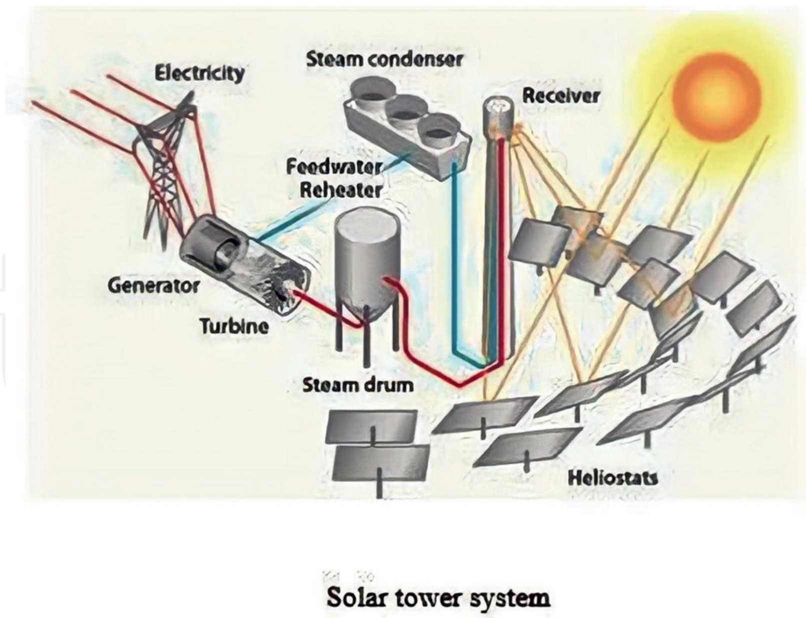

Figure 2.
Solar tower system - a solar tower system uses an array of mirrors to concentrate sunlight onto a central tower. This intense heat drives turbines to generate electricity, making it a promising solar energy technology with high efficiency and potential for large-scale power generation [adapted from: https://www.energy.gov/eere/solar/linear-concentrator-system-concentrating-solar-thermal-power-basics].

7. Merits of solar energy

The merits of solar energy are many.

1. As in the processing of solar energy, no pollutants are released into the atmosphere so solar energy can be deemed as a clean energy

2. Solar energy can be deemed as the mother of all energy that is present on Earth. Solar energy directly or indirectly gives rise to other forms of energy such as tidal energy and wind energy, all of which are non-polluting.

3. Solar energy may not be available to us all the time but the amount of solar energy that is received by us in the daylight, if stored properly, is more than enough to last us the whole day. To achieve this, photovoltaic cells and batteries are being used all over the world.

4. As per the researcher's data, the Earth receives almost 340 W/m^2 of solar energy on an hourly basis on a non-cloudy day. This vast amount of energy, if harnessed could help us eradicate all of Earth's energy crisis problems [8].

5. There are still areas in the world where there is still no electricity supply. Solar panels and photovoltaic cells give them an opportunity to gain access to electricity which is like a privilege to them. It helps in giving the underprivileged the wonders of electricity. The installation of solar panels and photovoltaic cells is very simple as it does not require wires and receivers. All we need for solar electrical energy is a solar panel and an installation area. Solar panels help cut

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energy consumption costs by over 20% over an elongated period of time. This cost-cutting is due to the fact that there is no additional fuel required to run the solar panel other than sunlight [5, 7].

8. Demerits of solar energy

1. Solar panels that are required to harvest solar energy are very expensive. The excess solar energy that is harvested must also be stored for future use, and the available storage solution is also costly. The converters and the inverters that are required to convert the direct current into alternating current and the device to ensure that the supply of current is uninterrupted are not cost-effective. This skyrockets the initial investment of solar panels, which is not affordable by everybody even if it gets cheaper in the long run.

2. Solar panels produce energy in the range of 50 to 180 W. To get a substantial amount of energy, the number of solar panels that are required is huge in number. This creates the problem of area deficiency as a huge number of solar panels require a large amount of area for the maximum output. This restricts people from buying solar panels.

3. Solar panels and photovoltaic cells that are required to convert solar energy to electrical energy are non-recyclable. Solar energy although non-polluting, the damaged photovoltaic plates are treated as garbage and add to the waste of the world.

4. The working and the output of the photovoltaic cells are weather-dependent as they are solely dependent on the amount of solar energy they receive from the sun on a particular day. If the day is cloudy, then it implies that solar cells cannot get the desired amount of solar energy they require to fulfill their needs.

5. The photovoltaic cells, solar energy storage, inverters, and converters, all are high maintenance machines. They require frequent maintenance from trained professionals otherwise they may lead to functional failure which will then mean both loss of money and more wastage for the world as they are not bio-degradable.

6. To get the maximum utilization of money and space, we need a huge number of photovoltaic cells. These photovoltaic cells require the production of single silicon crystal PV systems, which is very technically difficult, energy-intensive, and also very time-consuming [6, 7].

9. Wind energy

Wind energy is a renewable source of energy that has been gaining popularity in recent years due to its clean and sustainable nature. Turbines are used to convert the kinetic energy of wind into electrical energy. This energy production technique does not require any fuel, making it an appropriate option for those looking to reduce their carbon footprint. Wind power is also becoming cost-effective, because of technological advances that have made it more efficient and reliable.

Wind turbines are typically composed of a rotor, which consists of several blades that capture the wind's kinetic energy, and a generator, which converts this energy into electricity. The blades are designed to capture as much wind as possible while minimizing drag and turbulence. The generator then converts this mechanical energy into electrical energy, which can be used for various purposes such as powering homes or businesses [3].

The development of wind power has been driven by government policies that have created a market for renewable energies and by research and development in the field. Advances in control systems, rotor blade profiles, and power electronics have allowed for more efficient use of the wind's kinetic energy. This has resulted in lower costs for consumers while still providing clean and sustainable electricity.

In addition to providing clean electricity, wind power also has other benefits such as reducing air pollution from burning fossil fuels and creating jobs in the renewable energy sector. Wind turbines can also be used to supplement other renewable energies such as solar energy or hydroenergy [9, 10].

Overall, wind power is an attractive option for those looking to reduce their carbon footprint while still providing reliable electricity at reasonable costs. With continued research and development in the field, it is likely that wind power will continue to become more efficient and cost-effective in the future.

In the case of wind energy production, the most important part of this process is the conversion of the kinetic energy of the wind into electrical energy. For this conversion, a wind turbine is used. Over the past few years, average wind turbine ratings have grown almost linearly with current commercial machines rated at 1.5 MW.

Wind turbines are of two types namely horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). The two varieties of the vertical axis wind turbine (VAWT) are Darrieus and Savonius.

9.1 Horizontal axis wind turbine (HAWT)

A horizontal axis wind turbine, also known as HAWT, is a type of wind turbine that has a rotor blade assembly mounted horizontally on top of a tower. The rotor assembly consists of blades that rotate around a central hub, similar to a propeller. As the wind passes through the rotor blades, it causes the blades to rotate, generating mechanical energy that can be converted into electrical energy. HAWTs are the most common type of wind turbine used for large-scale commercial wind farms. They are typically more efficient than vertical-axis wind turbines and are capable of generating more electricity.

HAWTs can be installed onshore or offshore, and they can be used in a variety of wind conditions, making them a versatile option for renewable energy generation. One advantage of HAWTs is that they can be placed higher off the ground, allowing them to capture more wind energy. They are also easier to maintain and repair than vertical axis wind turbines, as the rotor assembly is mounted at ground level, making it easily accessible. However, HAWTs also have some disadvantages. They can be noisy and can pose a threat to birds and other wildlife. They also require a relatively large amount of space, which can be a challenge in densely populated areas. Overall, horizontal-axis wind turbines are an important part of the renewable energy mix and are likely to continue to play a significant role in meeting the world's energy needs in the coming years [11].

9.2 Vertical axis wind turbine (VAWT)

Vertical axis wind turbines (VAWTs) are innovative wind turbines that have been gaining popularity in recent years due to their unique design and efficiency. Unlike traditional horizontal axis wind turbines, VAWTs have their rotor shaft perpendicular to the ground, which allows them to capture wind.

9.3 Savonius

Unlike the Darrieus VAWT, it is a slow-rotating speed with a high torque machine. It can start at low wind speed, it does not need any external power source to turn on. It does not create so much noise as the Darrieus one. So, it is more environmentally friendly. It does not create any noise pollution. It can work in any wind direction [11].

9.4 Merits of wind energy

Wind energy is a renewable and sustainable source of power that is harnessed from the natural movement of wind. It has emerged as a popular alternative to traditional fossil fuels due to its numerous benefits. In this chapter, we will discuss the merits of using wind energy.

9.4.1 Wind energy is a clean and green source of energy

Wind energy is clean and does not produce any pollutants, such as carbon dioxide, sulfur dioxide, or nitrogen oxide, which can have harmful effects on the environment. Unlike fossil fuels, wind energy does not emit any greenhouse gases, which cause global warming and climate change. The use of wind energy can help reduce the carbon footprint of our energy consumption, making it a sustainable and environmentally friendly solution.

9.4.2 Wind energy is abundant and renewable

Wind energy is abundant and widely available in many regions around the world. As long as the sun shines and the Earth rotates, wind energy will continue to be generated. Wind energy is the fastest-growing renewable energy source in the world, and it is expected to continue to grow in popularity as technology improves and becomes more affordable.

9.4.3 Wind energy is cost-effective

The cost of wind energy has decreased significantly over the past decade, making it increasingly affordable for households, businesses, and governments to invest in. Additionally, once a wind turbine is installed, it has very low operating costs, making it an economically viable solution in the long run.

9.4.4 Wind energy can reduce dependence on fossil fuels

Wind energy can help reduce our dependence on fossil fuels, which are finite resources and have harmful effects on the environment. By using wind energy, we can reduce our reliance on non-renewable sources of energy such as coal, oil, and natural gas, and instead invest in sustainable energy solutions.

9.4.5 Wind energy creates jobs and boosts local economies

The wind energy industry creates jobs in many different areas, including manufacturing, construction, and maintenance. The development and construction of wind farms can also have a positive economic impact on local communities by creating new business opportunities and increasing revenue.

9.4.6 Wind energy is scalable and versatile

Wind energy can be used on a small or large scale, making it a versatile solution for a variety of energy needs. Wind turbines can be installed in remote areas to provide power to off-grid communities, or they can be installed in urban areas to provide power to businesses and households.

9.4.7 Wind energy can improve energy security

By diversifying our sources of energy, we can improve energy security and reduce our vulnerability to supply disruptions or price fluctuations. Wind energy is a reliable and consistent source of power, which can help mitigate the risks associated with energy supply insecurity.

9.4.8 Wind energy is low maintenance and long-lasting

Wind turbines require little maintenance once they are installed, and they have a lifespan of around 25 years. This means that they can provide a stable source of power for many years without significant upkeep costs.

9.4.9 Wind energy is noise-free and non-invasive

Modern wind turbines are designed to be quiet and produce very little noise pollution. Additionally, they are designed to have a minimal impact on the environment and wildlife, making them a non-invasive solution for sustainable energy production.

In conclusion, wind energy is a clean, abundant, cost-effective, and versatile source of power that offers numerous benefits over traditional fossil fuels. By investing in wind energy, we can reduce our carbon footprint, create jobs, boost local economies, and improve energy security. As technology continues to improve, wind energy is poised to become an even more attractive and viable solution for sustainable energy production [12, 13].

9.5 Demerits of wind energy

Wind energy is a popular source of renewable energy, but it has its demerits. In this section, we will discuss some of the disadvantages of wind energy.

1. Intermittency: Wind energy is an intermittent source of energy, which means that it is not available all the time. Wind speeds vary depending on weather conditions, time of day, and season. As a result, wind turbines may not produce energy at a constant rate.

2. Land use: Wind turbines require a lot of land to produce energy on a large scale. This can be a problem in areas where land is deficient. Wind turbines can also have negative impacts on wildlife habitats and migration patterns.

3. Visual pollution: Wind turbines can be seen as an eyesore by some people. They are tall and can be seen from miles away. This can be a problem in areas where there are strict regulations on the use of land and the preservation of natural beauty.

4. Noise pollution: Wind turbines produce noise pollution, which can be a problem for people living in the vicinity of wind farms. The noise can be constant and may affect the quality of life of those living near the turbines.

5. Maintenance costs: Wind turbines require regular maintenance to ensure that they operate at peak efficiency. This can be expensive and time-consuming, especially in offshore wind farms.

6. Bird and bat mortality: Wind turbines can cause bird and bat mortality. These animals can collide with the turbines and suffer fatal injuries. This can be a problem in areas where endangered species are present.

7. Wind energy is weather dependent: As wind energy is dependent on weather, it cannot be relied on to meet the energy needs of a region entirely. Energy storage systems like batteries can help to mitigate this problem, but they are still expensive and not widely used.

In conclusion, wind energy is an excellent source of renewable energy, but it is not without its demerits. The issues of intermittency, land use, visual and noise pollution, maintenance costs, bird and bat mortality, and weather dependency need to be considered when evaluating the potential of wind energy as a sustainable energy source [14, 15].

10. Geothermal energy

The word geothermal energy means energy developed from the inside of the Earth. So, geothermal energy is created by the intrinsic heat of the Earth. The high temperature and pressure in the Earth's core result in the melting of the metals where the high temperature originates from the movement of the tectonic plates and from the radioactive decay of materials.

Geothermal energy can be used in the generation of electricity or directly in space heating, aquaculture, laundry, and industrial processes. Geothermal energy can be found in abundance in hot springs all over the world.

Among these four types, that is, hydrothermal, hot dry rock, magma, and geopressured, only hydrothermal resource is used commercially while the other three resources are still under development. Although hydrothermal energy is being commercially applied in many places, other types of geothermal energy are also used intermittently [3, 16].

10.1 Dry steam technology

Dry steam power plants draw energy from underground resources like steam. The steam is piped directly from underground wells to the power plant where it is directed into a turbine or generator unit which in turn generates electricity. Here, the condensate is usually re-injected into the reservoir or used for cooling.

There are only two known underground resources of stream, The Geysers in Northern California and Yellowstone National Park in Wyoming [17].

10.2 Flash steam technology

Flash steam power plants are the most common type. They use geothermal reservoirs of water with temperatures greater than 455 K. This very hot water flows through wells in the ground under its own pressure. As it flows upward, the pressure decreases and some of the hot water boils or flashes into steam. The steam is then separated from the water and used to power a turbine. Any leftover water and condensed dew are injected back into the reservoir, making this a sustainable resource. The remaining hot water may flash again twice or maybe even three times, at progressively lower pressures and temperatures to obtain more steam. They are the least expensive out of the three geothermal harvesting technologies in both building and operating. They are also the least prone to chemical precipitation problems due to the source of energy being the steam that is formed in flash steam technology [17, 18].

10.3 Binary cycle technology

Binary cycle power plants operate on water at lower temperatures of about 380 to 455 K. These plants use the heat from the hot water to boil a working fluid usually an organic compound with a low boiling point and the working fluid is vaporized in a heat exchanger and used to turn a turbine. The water is then injected back into the ground to be reheated. The water and the working fluid are kept separated during the whole process, so there are little to no air emissions. A higher temperature range provides thermal stability of the working fluid, while the lower temperatures are more feasible in terms of techno-economic and financial factors. Further, the impacts of corrosion and scaling are not apparent at high temperatures, as there is no contact between the power generation equipment and the geo-fluid. These plants are the most versatile of all and the functionality of power is determined by the second cycle [17].

10.4 Merits of geothermal energy

Geothermal energy is a type of renewable energy that is generated by the Earth's internal heat. It has several advantages over other forms of energy, including its availability, sustainability, reliability, and low environmental impact.

1. Availability: Geothermal energy is a renewable energy source that is available at any time. Unlike solar and wind energy, geothermal energy is not dependent on weather conditions or the availability of sunlight or wind. This makes it a reliable source of energy that can be used to meet the demands of a wide range of applications.

2. Sustainability: Geothermal energy is a sustainable energy source because it is continuously replenished by the Earth's internal heat. The amount of heat produced by the Earth's core is estimated to be about 42 million megawatts, which is more than enough to meet the world's energy needs. Unlike fossil fuels, which are finite resources, geothermal energy will not run out as long as the Earth's internal heat is available.

3. Reliability: Geothermal energy is a reliable source of energy because it is not affected by weather conditions. Unlike solar and wind energy, which can be intermittent, geothermal energy can be generated consistently throughout the year. This makes it a reliable source of energy for base load power generation, which is the minimum amount of power required to meet the energy demands of a particular region.

4. Low Environmental Impact: Geothermal energy has a low environmental impact compared to other forms of energy. The process of generating geothermal energy does not produce greenhouse gas emissions, which contribute to climate change. The use of geothermal energy also does not produce harmful pollutants, which can have negative impacts on human health and the environment. In addition, the land use requirements for geothermal power plants are relatively small compared to other types of power plants.

5. Cost-effective: Geothermal energy can be a cost-effective source of energy for power generation. Although the upfront costs of building geothermal power plants can be high, the operating costs are relatively low compared to other types of power plants. This is because the fuel source for geothermal power plants is free, which reduces the overall cost of generating electricity. In addition, the long lifespan of geothermal power plants, which can last up to 30 years or more, reduces the need for frequent replacements or maintenance, which can further reduce the overall cost of generating electricity.

6. Versatility: Geothermal energy can be used for a wide range of applications, including power generation, heating and cooling. In addition, it can be used in combination with other renewable energy sources, such as solar and wind energy, to create hybrid systems that can provide a more stable and reliable source of energy.

7. Local development: The development of geothermal energy can provide benefits to local communities. For example, geothermal power plants can provide a source of revenue for local governments, which can be used to fund local projects and services. In addition, the development of geothermal energy can provide energy security and independence for local communities, reducing their reliance on imported fossil fuels.

8. Reduced energy dependence: The use of geothermal energy can reduce a country's dependence on imported fossil fuels. This can help to improve energy security and reduce the impact of fluctuations in global energy prices. In addition, it can reduce a country's carbon footprint [19, 20].

10.5 Demerits of geothermal energy

However, like all sources of energy, geothermal energy also has its demerits that limit its potential for widespread use.

1. Limited availability: Geothermal energy is not available in all parts of the world. It can only be harnessed in areas where there is enough heat beneath the Earth's surface. These areas are limited to regions with active volcanoes, hot springs, and

geysers. This means that geothermal energy cannot be used as a primary source of energy in areas without these natural features.

2. High upfront costs: The initial cost of building a geothermal power plant is relatively high. The cost of drilling, constructing, and maintaining the wells and the power plant is expensive. The cost of geothermal exploration can also be significant. These high upfront costs can make it difficult for companies and governments to invest in geothermal energy.

3. Environmental impact: Although geothermal energy is a clean source of energy, it can still have a negative impact on the environment. The construction of geothermal power plants can disrupt natural habitats and wildlife. The drilling and injection of water into the Earth can also cause earthquakes and other seismic activities.

4. Limited lifespan of wells: Geothermal wells have a limited lifespan. Over time, the wells can become clogged with minerals and sediment, reducing their efficiency. In some cases, the wells can also become contaminated, making them unusable. This means that geothermal power plants require continuous maintenance and monitoring to ensure their longevity.

5. Energy production fluctuation: Geothermal energy production can be affected by natural events such as earthquakes and volcanic eruptions. These events can disrupt the flow of heat and water, reducing the efficiency of the power plant. This fluctuation in energy production can make it difficult for power plants to meet the electricity demand.

6. Limited scalability: Geothermal power plants have limited scalability due to the limited availability of geothermal resources. This means that the energy produced by geothermal power plants cannot be increased beyond a certain point. This makes it difficult to use geothermal energy as a primary source of energy for large-scale industrial operations.

7. Water usage: Geothermal power plants require a significant amount of water to operate. The water is used to extract heat from the Earth and to generate steam to power turbines. This can put a strain on local water resources, especially in areas where water is deficient in nature.

In conclusion, geothermal energy has its demerits, including limited availability, high upfront costs, environmental impact, limited lifespan of wells, energy production fluctuation, limited scalability, and water usage. These demerits limit the potential for widespread use of geothermal energy. However, with continued technological advancements and innovations, it is possible that some of these demerits can be mitigated, making geothermal energy a more viable source of renewable energy in the future [21].

11. Hydrothermal energy

Hydrothermal energy is classified into two categories. One in which the water is heated up using other sources and the heated water produces vapors that in turn rotates a turbine, and in the process produces energy. Another form of hydrothermal energy is decomposing multiple biodegradable materials underwater at a high temperature and pressure and increasing the carbon and calorific content of the waste that is being decomposed. This process is globally known as hydrothermal carbonization.

11.1 Conventional hydrothermal energy

It is well known that tectonic activities along plate margins are controlled by thermal processes induced by density contrasts and changes in rheology. Vice versa, the tectonic movements could lead to heat accumulation because of differences in the thermal capacities of different strata. This heat trapped in different layers can then be used to heat up the water bodies and produce hydrothermal energy. This hydrothermal energy also helps in understanding the tectonic plate movements, the formation and distribution of geothermal resources, water-rock interactions, and the concentration of ore-forming elements.

Besides the study of tectonics, the heat anomaly in the hydrothermal reservoir might be a result of groundwater movement. In a high-temperature and high-pressure environment, the coupled effect of water and heat serves as the driving forces of groundwater flow. It further dominates the dynamics of deep hydrothermal circulations.

Traditionally, hydrothermal systems only refer to the flow and heat transport processes that redistribute energy and mass in response to circulating fluids such as groundwater and brine (**Figure 3**).

The total geothermal energy in these basins is 2.5 × 1022 J, which is about 260 times the total energy consumed in China in the year 2010. The utilization of hydrothermal resources is undergoing rapid development and strong growth can be further expected. Incidentally, there is still a huge potential for hydrothermal systems that have not been fully exploited. Secondly, the Enhanced Geothermal Systems (EGS) are still in the experimental and pilot stage, which is far from maturity for commercial use. Thirdly, the cost of hydrothermal utilization is generally under 2 ¢/kWh for space heating and 4 ¢/kWh for electric generation, while the lowest possible cost for the utilization of EGS is 5.43 ¢/kWh.

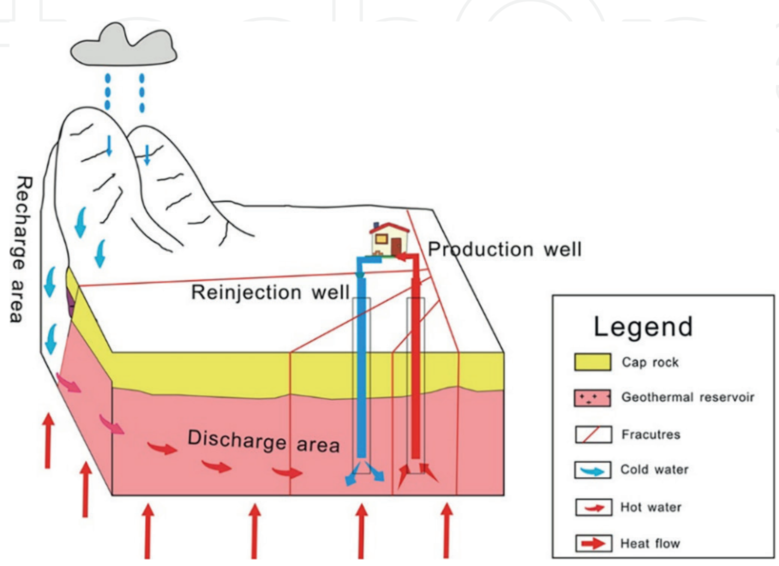

Figure 3.
The conceptual model of reservoir engineering in the hydrothermal systems (adapted from [22]).

We also learned from the case studies that reinjection is absolutely essential for the sustainable utilization of hydrothermal systems. The drawdown of the groundwater table during exploitation is a limiting factor to the long-term, sustainable application of hydrothermal resources.

On the topic of reinjection operation, scientific and technical challenges still remain. For example, the low permeability of sandstone formations and the clogging of reinjection wells often lead to higher costs [22–24].

11.2 Sludge preparation by hydrothermal energy

HTC was applied to stabilize and process sludge collected from septic tanks into hydrochar for practical energy recovery. Hydrothermal carbonization (HTC) is a thermal conversion process that can be used to treat fecal sludge (FS) and convert it into a valuable solid product called "Hydrochar." The process requires short reaction times (1–12 h) at a relatively low-temperature range (180–250°C), with corresponding pressures of up to 30 bar. HTC is applied to stabilize and process FS collected 20 from septic tanks into hydrochar so that pathogens are destroyed and energy recovery is possible.

The study involved using a 1-L high-pressure stainless steel reactor, fitted with a pressure gauge, thermocouple, and gas collection ports. An electric heater with a control panel was used to regulate the reactor temperature and reaction time. The HTC experiment was carried out three times using 350 mL of FS mixed with different additives such as catalysts and biomasses. The process was controlled at a heating rate of 6°C per minute, temperature of 220°C, and reaction time of 5 hours. The pressure inside the reactor was maintained at 30 bar. After each experiment, the reactor was rapidly cooled to ambient temperature using water in a cooling jacket at a rate of about 45°C per minute to stop the reaction. The remaining carbonized FS in the reactor was separated into liquid and solid hydrochar using vacuum filtration (Whatman filter paper, 1.2 μm). The hydrochar was dried in an oven at 105°C for at least 12 hours to remove any remaining moisture. The produced hydrochar was analyzed to determine its characteristics. The mixtures of FS and the selected catalyst or biomass were further tested in the HTC reactor operating at different temperatures and reaction times. The study determined the effects of process parameters such as temperature and reaction time and identified the optimum conditions of the HTC process.

HTC changed the fuel properties of cellulose, along with the results of the ultimate and proximate analyses. The fixed carbon content of cellulose increased from 6.1 to 35.0% in response to HTC at 220°C (**Figure 4**). This result suggests that the cellulose begins to decompose at 220°C. As the fixed carbon content increased during HTC, the calorific value of cellulose increased from 16.5 to 18.9, 23.1, 26.5, and 27.7 MJ/kg at 180, 200, 220, and 280°C, respectively. These increased calorific values can be used to calculate the final effect of HTC over the quality of the biofuel

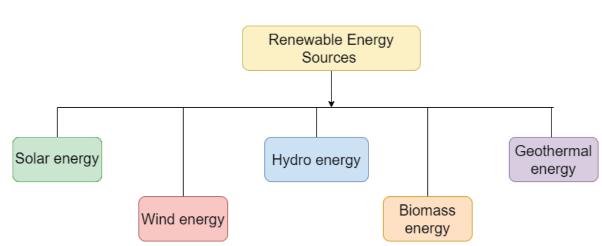

Figure 4.
Classification of different types of renewable energy resources.

(i.e., biochar) obtained from lignocellulosic biomass. This effect can most likely be attributed to the decomposition or pyrolysis of cellulose during HTC reactions owing hydrolysis, chemical dehydration, and decarboxylation reactions.

The HTC process can improve the properties of cellulose in a manner similar to the coalification process. The coalification bands of pure cellulose and its biochar were compared with the coalification bands of various types of coal.

Cellulose is known to have high H/C and O/C ratios, similar to other biomass materials. The H/C and O/C ratios of cellulose decreased with the coalification status between lignite and sub-bituminous coal. This occurred when the cellulose was converted into carbonaceous products by chemical dehydration reactions during HTC [25].

11.3 Merits of hydrothermal energy

Hydrothermal energy is considered a renewable and sustainable energy source as it takes its heat from the Earth's core, meaning that it is essentially inexhaustible. Unlike some other renewable energy sources like wind and solar, hydrothermal energy is available constantly, providing a consistent source of power.

1. It also produces very low levels of greenhouse gas emissions when compared to fossil fuels, making it an environmentally friendly option.

2. Geothermal power plants also have relatively low operating costs, providing stable and predictable energy prices for consumers.

3. Furthermore, they can also provide baseload power, meaning they can meet the constant electricity demand without fluctuations.

11.4 Demerits of hydrothermal energy

On the other hand, geothermal energy resources are limited to regions with suitable geological conditions, meaning its widespread adoption is restricted.

1. Additionally, building a geothermal power plant can be expensive due to the need for exploration and drilling to identify suitable geothermal reservoirs, providing a high upfront cost.

2. Lastly, over time, geothermal reservoirs can become depleted, which reduces energy output and may necessitate the abandonment of a geothermal well. It can limit the long-term sustainability of individual geothermal projects [25].

12. Biomass energy

Biomass energy is a renewable energy source that is produced from organic matter, such as plants, trees, and waste materials. Biomass energy is considered a sustainable alternative to fossil fuels because it is carbon neutral and has the potential to reduce greenhouse gas emissions. In recent years, the use of biomass energy has increased due to concerns about climate change, energy security, and the need to diversify energy sources.

Biomass energy can be produced in several ways, including combustion, gasification, and anaerobic digestion. Combustion is the most common method of biomass energy production, which involves burning biomass to produce heat and electricity. Gasification is a process that converts biomass into a gas, which can be used for heating or electricity generation. Anaerobic digestion is a process that breaks down organic matter in the absence of oxygen, producing biogas that can be used for heating or electricity generation.

Biomass energy can be derived from a variety of sources, including agricultural and forestry residues, municipal solid waste, energy crops, and algae. Agricultural and forestry residues include crop residues, such as corn stalks and wheat straw, and forestry residues, such as tree branches and sawdust. Municipal solid waste includes household garbage, social waste, and industrial waste. Energy crops are crops that are grown specifically for energy production, such as switchgrass and sugarcane. Algae is a type of aquatic plant that can be used to produce biofuels, such as biodiesel and bioethanol.

Biomass energy has several advantages over fossil fuels. One of the primary advantages of biomass energy is that it is a renewable energy source. Unlike fossil fuels, which are finite resources that will eventually run out, biomass can be continually replenished through sustainable practices. Another advantage of biomass energy is that it is carbon neutral. When biomass is burned or converted into energy, it releases carbon dioxide into the atmosphere. However, because the carbon dioxide released during biomass combustion is equal to the carbon dioxide that was absorbed by the plant during its lifetime, biomass energy does not contribute to a total increase in atmospheric carbon dioxide (CO_2) levels [16].

Biomass energy also has the potential to reduce greenhouse gas emissions. By using biomass energy instead of fossil fuels, the amount of carbon dioxide emitted into the atmosphere can be reduced. This is because biomass energy is a low-carbon fuel source that produces fewer emissions than fossil fuels. Additionally, biomass energy can help to reduce waste by using organic materials that might otherwise end up in landfills. Despite its advantages, biomass energy also has some drawbacks. One of the primary drawbacks of biomass energy is that it can be expensive to produce. Biomass energy requires significant upfront investment in equipment and infrastructure, and the cost of biomass feedstocks can be volatile. Additionally, biomass energy can have negative environmental impacts if it is not produced sustainably. For example, clearcutting forests to produce biomass energy can result in habitat destruction and loss of biodiversity.

In conclusion, biomass energy is a renewable energy source that has the potential to reduce greenhouse gas emissions and diversify energy sources. Biomass energy can be produced from a variety of sources, including agricultural and forestry residues, municipal solid waste, energy crops, and algae. While biomass energy has several advantages over fossil fuels, including its renewability and carbon neutrality, it also has some drawbacks, such as high production costs and negative environmental impacts. As research and technology continue to advance, it is likely that biomass energy will play an increasingly important role in the global energy mix [26, 27].

12.1 Merits of biomass energy

i. Biomass is a renewable resource as we can regenerate the lost biomass by growing new crops and trees, making it a sustainable energy source.

ii. As biomass combustion releases CO_2, the same amount of CO_2 is absorbed by the plants used for biomass, forming a carbon-neutral cycle. This, in turn, reduces net greenhouse gas emissions.

iii. Biomass energy is a great alternative to landfills and open burning, as it makes use of agricultural and forestry residues for energy production, thus cutting back on waste.

iv. Since biomass can be sourced locally, it promotes energy independence and reduces reliance on foreign energy sources.

v. We can source biomass energy from a variety of organic materials, providing flexibility in utilization.

vi. With the cultivation and processing of biomass, rural populations can earn jobs and income, promoting energy production in such regions [8, 28].

12.2 Demerits of biomass energy

i. While biomass is considered carbon-neutral over the long term, burning biomass releases CO_2, methane (CH4), and other pollutants into the atmosphere. The carbon neutrality assumption depends on the replanting and growth rates of biomass feedstock, which may not always be guaranteed.

ii. Biomass combustion can produce air pollutants, including particulate matter, nitrogen oxides (NOx), and volatile organic compounds (VOCs), which can have adverse health effects and contribute to smog and air quality issues.

iii. Large-scale biomass production can lead to land-use changes, deforestation, and increased water consumption, potentially impacting ecosystems and water resources.

iv. Biomass energy conversion processes, such as combustion and gasification, are often less energy-efficient than other renewable sources like wind and solar, which can limit their overall environmental benefits.

v. Biomass energy conversion processes, such as combustion and gasification, are often less energy-efficient than other renewable sources like wind and solar, which can limit their overall environmental benefits.

vi. Using land for biomass production can compete with food production and natural habitats, raising ethical and environmental concerns.

vii. Biomass often needs to be transported from rural areas to energy facilities, which can be logistically challenging and energy-intensive, affecting overall efficiency [8, 28].

13. Recent works

There has been a plethora of projects on green energy and chemistry that have been recently adopted by multiple institutions. One of them is the transmission of data using green radio. The specific objective of the Green Radio program is to investigate and create innovative methods for the reduction of the total energy needed to operate a radio access network and to identify appropriate radio architectures that enable such a power reduction. These results clearly show that reducing the power consumption of the base station or access point has to be an important element of this research program. Studies have indicated that the mobile handset power drain per subscriber is much lower than the base station component. Hence, the Green Radio project will mainly focus on base station design issues. This is because the lifetime of a base station is typically 10–15 years, compared to a typical handset being used for 2 years. In addition, the energy costs of a base station are shared between multiple mobile subscribers, leading to a large imbalance in the contribution of embodied energy. From the point of view of devices, significant efforts need to be put into reducing manufacturing energy costs and increasing their lifetime. The Third Generation Partnership Project (3GPP) Long Term Evolution (LTE) system has been chosen as the baseline technology for the research program; its specifications have recently been completed with a view to rolling out networks in the next two to 3 years [29].

Energy can also be gained from the recycling of aircraft's vibration. This can be achieved using the characteristic properties of piezoelectric that convert the vibrational energy into piezoelectricity. Piezoelectricity is the ability of some materials to generate an electric potential in response to applied mechanical stress. This may take the form of a separation of electric charge across the crystal lattice. If the material is not short-circuited, the applied charge induces a voltage across the material [30]. Green chemistry can also be used to produce energy with green technology by Planet-e from living plants and Bacteria. The Plant-Microbial Fuel Cell (P-MFC) is a novel technology that generates electricity in a renewable and likely sustainable way. The P-MFC may mature into a very competitive technology toward other bio-energy systems as it can deliver a net five times higher energy than other systems. The P-MFC concept has several attractive qualities, which can provide a significant breakthrough for sustainable energy production. The plants convert solar energy into organic matter, which is transformed into electricity by electrochemically active bacteria in the fuel cell. Still, the high power output must be maintained, and costs must be reduced to become compatible. Further research and development will reinforce the competitiveness of Europe since P-MFC is worldwide implementable. It has been shown that both the size and type of carbon granules affect the current density of the PMFC. The cathode of the P-MFC can limit the power output [31].

14. Barrier

Implementing green chemistry practices in the field of energy efficiency faces several associated barriers that hinder progress in creating sustainable and environmentally friendly energy solutions. One prominent challenge is the inertia of established industrial processes and technologies, which often resist change due to their long-standing presence and large investments. What's more, there can be economic constraints, as the development and adoption of green chemistry methods may require upfront investments in research and development, making it difficult for some companies to justify the costs. Regulatory barriers, such as outdated or inadequate environmental regulations, can also impede the adoption of greener practices. Furthermore, the lack of awareness and education about green chemistry among stakeholders in the energy sector can slow down its implementation, as it requires a shift in mindset and a commitment to sustainability. Finally, the inherent complexity of energy systems and the need for interdisciplinary collaboration between chemists, engineers, and policymakers pose challenges in developing holistic green chemistry solutions for energy efficiency. Addressing these barriers will be essential to drive the widespread adoption of green chemistry principles in the pursuit of sustainable energy solutions [32].

15. Conclusion

This review highlights the various forms of green energy that we have at our disposal. Though we look at green energy as an alternative source of energy for us in the future, in reality, it might be the only source of energy left for us to explore. The utility of renewable energy and green technology also minimizes the dependency on fossil fuels in the era of global development.

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