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Review

Renewable Energy Resources Technologies and Life Cycle Assessment: Review

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Abstract: Moving towards RER has become imperative to achieve sustainable development goals (SDG). Renewable energy resources (RER) are characterized by uncertainty whereas, most of them are unpredictable and variable according to climatic conditions. This paper focuses on RER-based electrical power plants as a base to achieve two different goals, SDG7 (obtaining reasonably priced clean energy) and SDG13 (reducing climate change). These goals in turn would support other environmental, social, and economic SDG. This study is constructed based on two pillars which are technological developments and life cycle assessment (LCA) for wind, solar, biomass, and geothermal power plants. To support the study and achieve the main point, many essential topics are presented in brief such as fossil fuels' environmental impact, economic sustainability linkage to RER, the current contribution of RER in energy consumption worldwide and barriers and environmental effects of RER under consideration. As a result, solar and wind energy lead the RER electricity market with major contributions of 27.7% and 26.92%, respectively, biomass and geothermal are still of negligible contributions at 4.68% and 0.5%, respectively, offshore HAWT dominated other WT techniques, silicon-based PV cells dominated other solar PV technologies with 27% efficiency, combustion thermochemical energy conversion process dominated other biomass energy systems techniques, due to many concerns geothermal energy system is not preferable. Many emerging technologies need to receive more public attention, intensive research, financial support, and governmental facilities including effective policies and data availability.

Keywords: sustainable development; renewable energy resources; life cycle assessment; wind energy; solar energy; biomass energy; geothermal energy

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1. Introduction

The electrical power sector earns its importance from the rapid growing of electricity demand as a result of the electrification of different sectors such as households and transportation. Due to the rapid increase in the demand for electric power, electricity generation consumes more and more energy resources. Generating electricity based on RER contributes a 76% reduction in CO_2 [1]. Although the transition towards RE is costly, it would reduce the bill for improving environmental conditions and human health. Also, the prices of fossil fuels are increasing rapidly [2]. According to the levelised cost of energy indicator, the claim that renewables are expensive has been refuted. The evidence for that is: the falling cost of wind and solar technologies has exceeded most expectations. By 2030, the renewables and storage system would be far cheaper compared to fossil fuel and nuclear energy [3]. A 100% economic renewable energy system could be achieved by 2050 especially on the regional level through technological development, interconnection, storage systems and regulations [4].

Energy is a basic pillar in SD which is constrained by climate-change issues to reduce GHG emissions. Nowadays, SD has evolved to include four themes which are sub-goals of SED. Firstly, obtaining a modern energy service for reasonable prices. This means available affordable energy sources. Secondly, sustainable energy supplies means a transition toward environmentally friendly energy sources. Thirdly, consuming sustainable energy, which means changing the current generation and consumption style. Fourthly, securing energy sources which means providing sufficient quantities of energy at all times with different shapes at affordable prices [5].

The electrical power system SD is influenced by RER as follows: reducing GHG emission, increasing environmental awareness, providing more investment opportunities, and producing several economic benefits partially and entirely. Also, it helps to provide a reduced operating cost, secured energy, reliable power system, high-quality energy, enhanced employment sector, local and national development, and a reduced carbon footprint. RER is characterized by intermittent nature and uncertainty, so it requires efficient energy storage system and advanced control techniques. Generating electricity from RER needs a special vision, large investments, and developed technology. Economic effects of RER for developed countries are not all the same for developing countries. In general, the electrical power sector is derived from a green economy to meet load growth and climate change [6].

Sustainable energy development could be achieved by saving in consumption, optimum and efficient generation, and transitioning towards RER. A replacement of fossil fuels reduces air pollution, decreases carbon emission and improves weather conditions. Energy and economy are tightly correlated to each other. Satisfying human needs, economic growth, standard of living and welfare are directly influenced by energy supplies. Obtaining affordable, efficient and stable energy sources is a crucial factor to develop the global economy. For instance, in USA the effect of the energy system on the economy could be explained by four indicators: gross domestic product (GDP), trade, employment and welfare. A transition towards RER could be summarized into the following points: providing clean sustainable affordable energy, providing more job opportunities in manufacturing, construction, maintenance and utilities, a transition of workers from mining sector toward recent decarbonized sectors, increasing GDP, and trade and welfare, and this transition needs several decades [7].

The introduction addresses many items related to RER and sustainable developments in order to adequately shine light on the purpose of the paper as follows:

- Objective and contribution
- Concepts and definitions
- Sustainable development and renewable energy
- Fossil fuels and their impacts on environment and human health
- Current situations of renewable energy
- Green investment and economical sustainability

1.1. Objective and Contribution

The main objective of the study is to achieve SDG7 (obtaining reasonably priced clean energy) and SDG 13 (consideration of climate change). These goals in turn would support other environmental, social and economic SD goals. This could be achieved throughout studying RER technological advancement and RER life cycle assessment. The contribution of this paper could be summarized as follows:

- Providing a technological review for wind, solar, biomass and geothermal RER
- Providing a life cycle assessment review for each type under consideration
- Addressing the environmental impact of each type
- Studying challenges that prevent the growing of RER power plants

1.2. Concepts and Definitions

There are some definitions that need to be explained in order to understand the SD. These definitions are renewable, green, clean, sustainable and alternative energy. Renewable energy (RE) comes from natural resources that are renewable and never ends over time. RE resources include wind, solar, wave, biomass and geothermal. Green energy is the source of energy that produces lower levels of greenhouse gases so it has a less harmful environmental effect. Green energy resources include solar, wind, fuel cell, storage devices, hydro, geothermal, wave and bioenergy. All green energy resources are expected to be a renewable type of energy. Clean energy is an energy resources that has no harmful emissions nor greenhouse gases during the generation process. Clean energy includes nuclear energy besides renewable and green energy. The development of clean energy is continuing based on rare earth materials such as dysprosium, terbium, neodymium and yttrium. Sustainable energy is energy that is produced from a persistent source of energy that is sustainable and cannot be depleted. For instance, wind, solar, hydro and geothermal are a sustainable type of energy. Sustainable energy includes all RE types excluding biomass. Alternative energy is the energy produced from any source other than fossil fuels. It includes sustainable, renewable, and clean energy sources [8,9].

1.3. Sustainable Development and Renewable Energy

Sustainable development (SD) as a concept appeared in the eighties of the last century. Essentially, the concept related to satisfying basic human needs such as socio-economic development, keeping the environment clean, and ensuring quality of life for human being. Sustainable energy development (SED) expression is complex and multi-dimensional. This expression depends on the user itself. After introducing energy SD goal 7 by United Nations (UN), it became a prominent policy worldwide. SD could be categorized into three parts: environmental, social, and economic sustainability. Balancing these three parts, which is not easy, could achieve SD [10]. Achieving SD requires clean sustainable energy sources: using a proper technology, using strategic policy, attractive economic incentives, and suitable use of available resources. Energy production from alternative sources is cheap compared to energy produced from fossil fuel and nuclear plants. The shape of world energy is reshaped according to RER developments [11].

The United Nations General Assembly (UN-GA) announced sustainable development goals (SDG) in 2015 which is known as the 2030 agenda. Seventeen SDG have been introduced to guarantee environmental, social and economic SD and a better future for all. These SDG could be listed as follows: eliminating poverty and hunger; providing healthy lives, quality education, gender equality, portable water and sanitation for all; reasonably priced and clean energy; acceptable work and growing economy; industry, innovation, and infrastructure; reduced inequalities; sustainable cities and communities; fair sustainable consumption and production; consideration of climate change; effective use of water resources for SD; consideration of ecosystem; peace, justice and strong effective institutions; restoring partnerships for SD. Some goals reinforce each other and some are opposite to each other. To achieve SD, trade-offs between these goals have to be made [12]. SD includes social, economic and environmental dimensions. Studying the long-term linkage of gross domestic product (GDP), corruption, GHG and RER showed a tight correlation between these dimensions. Economic growth could be achieved through increasing GDP, resisting corruption, applying clean and renewable technologies and attracting green investments [13].

Renewable energy, environment and sustainability have been intensively studied during 2020–2021. The research work has focused on the following topics: the effect of COVID disease on renewable energy resources (RER), SD and ecological footprint; photovoltaic efficiency, defects, technologies and stability of elements; nanostructured materials and semiconductors; energy storage of clean energy and high energy density; energy conversion technologies. The most cited research belongs to authors from Asia, concentrated on power system efficiency and security. Although computer science was not sufficiently applied in the field of renewable, environmental and SD, it will increase gradually [14]. Natural resources should be used efficiently to enhance national security and economic SD. Optimization of available RER has become an imperative, not a luxury. Modern economies depend on the availability of different energy resources with a suitable share of natural resources. This appeared clearly in energy crises as in the situation in Europe when Russia stopped gas supplies after the invasion of Ukraine. As a result, most European countries have increased RER shares of the total energy production [15].

1.4. Fossil Fuels and Their Impacts on Environment and Human Health

Conventional energy sources (CES) are a nonrenewable energy source that dominated energy consumption for many years until the advent of RER. CES include fossil fuels and nuclear energy. Fossil fuels comprise coal, crude oil, petroleum and natural gas. They have been used as the main source for energy production, transportation and industry for many years [16]. Fossil fuels supply most of the required energy worldwide. Combustion of fossil fuels causes a severe environmental problem by releasing greenhouse gases (GHG) such as methane as well as oxides of carbon and nitride. Exponential growth in load demand increases emissions of GHG which causes climate change, increasing sea level and severe health problems. Fossil fuels are unsustainable and exposed to depletion. Also, the prices are increasing rapidly. On the other hand, RER are environment friendly, cost-effective, sustainable, require less maintenance and have moderate efficiency. Based on these facts, many countries around the world starts to rely on RER [17,18].

As an important source of energy, fossil fuels have three indicators which are very important. These indicators are energy mix, energy consumption and depletion. Fossil fuels energy mix represents the contribution of each type to the total fossil fuels energy. Fossil fuel energy consumption represents the consumed fossil fuel energy to the total energy consumption. Fossil fuel depletion represents the proven reserves of fossil fuels to the gross annual production [19]. Due to environmental concerns, the consumption of natural gas is gradually increasing while the consumption of coal and oil is gradually decreasing. However, fossil fuels still have the highest share in total electricity production. Policymakers could not restrict the use of fossil fuels to keep economic growth [20].

Fossil fuel consumption has two major concerns, environmental degradation and depletion of nonrenewable resources. Environmental degradation is characterized by climate change, air pollution, increasing global warming, extinction of habitat and species, freshwater shortage and unbalanced ecosystem. Fossil fuels are non-recyclable so, depletion of fossil fuels increases the hazardous energy security, fluctuation of prices and unstable markets. Also, it has a negative social effect because of health problems [21–23]. Another issue is human health which is badly affected directly and indirectly by fossil fuels consumption, as well as the inevitable cost to treat the consequences. The relationship between fossil fuels consumption and mortality has been studied for the Commonwealth of independent states which mainly depend on fossil fuel with a small contribution of RE systems. The obtained results show that there is a positive proportional relation between carbon dioxide emission rate and mortality from cardiovascular disease, cancer and chronic respiratory disease [24].

Young children are greatly affected by the consequences of air pollution due to their weak defense mechanisms especially in low-income countries because of poverty and improper medical care. They are subjected to chronic diseases such as respiratory system disease. Not only health issues but they are also subjected to a decreased ability to learn, weak cognitive and behavioral development, and less contribution to society's development. The inevitable consequences due to fossil fuel consumption will affect the future of our children, their offspring and the human race. The world would become unsustainable, and unfair and it would be hard to adapt, grow and survive [25].

Reduction in fossil fuel consumption resulting from Coronavirus pandemic has greatly improved environmental conditions. Coronavirus pandemic has caused significant changes in human activities. Most countries have moved toward lockdown to suppress the disease which caused a great reduction in fossil fuel consumption. This caused unexpected global environmental changes in 2020 compared to 2019. Air pollution has been reduced significantly. Sixteen percent reduction in Ozone formation. Earth acidification effect has reduced by 15.16%. Reduction of freshwater toxicity by 23.0%. Marine toxicity has been reduced by 22.77%. Land used has been reduced by 21.89%. The increasing availability of mineral resources by 11.1% [26].

1.5. Current Situations of Renewable Energy

RER-based generating capacity is gradually increased over years. Despite the severe effect of the COVID-19 pandemic, RER installed capacity is 38% of the global installed capacity at the end of 2021. RER added 257 Giga Watts (GW) which increased the percentage of RER-based power generation by 9.1%. The solar energy (SE) installed capacity is 133 GW which is almost half of the installed RER. Wind energy (WE) comes next with 93 GW which is almost 40% of the installed RER. The global RER installed capacity increases linearly as shown in Figure 1. It starts at 1443.923 GW in 2012 and increased to 3063.926 GW in 2021. The contribution of SE increased rapidly. The installed SE was 104.312 GW (7% of installed RER) at the end of 2012 and reaches 849.473 GW (28% of installed RER) at the end of 2021. Also, the majority of the installed SE is photovoltaic type. China comes first with 33% followed by the USA with 10.6%, then Germany with 4.5% and Japan with 3.6%. By 2030, RER are expected to contribute 40% of the total generated power [27]. All types of RE add a considerable capacity every single year except for marine energy which add nothing in 2015 and 2021. The big share comes from hydropower which is one of the oldest sources of energy. The hydro energy adding rate is not too much, however, it is still superior to other sources. SE comes next with the highest adding rate. WE systems come third with a considerable increase. Bioenergy sources come next with a 4.68% share with a considerable adding rate. The capacity share of geothermal and marine energy sources comes last with 0.5% and 0.017% respectively with a smaller adding capacity.

The installed capacity for RER is increased rapidly for different parts of the world as illustrated by Figure 2. Most of RER's installed capacity is founded in Asia. Europe comes next followed by North America. South America comes fourth followed by Eurasia. Africa comes last with the least installed capacity [27]. For all parts of the world, hydro energy presents the most installed capacity and marine energy which is concentrated in Asia and Europe has the least capacity.

The Russian invasion of Ukraine has severely affected energy and agriculture markets. Securing energy sources becomes a matter of death. Many countries especially in the European Union have accelerated the transition toward RE. This is to secure an alternative source of energy instead of Russian natural gas. It is expected for the installed capacity of RER to exceed 300 GW (8%) and for the solar photovoltaic (SPH) installed capacity to exceed 190 GW (25% gain). The 17% deficit in annual wind capacity is compensated by solar PV. RER is expected to hit a new record in 2023, especially for SPH which is predicted to reach 200 GW. Since the beginning of the year 2021, the prices of PV and WE systems have greatly increased due to incredible increases in freight costs, prices of raw materials, manufacturing costs, and high prices of power. The overall investment costs for PV and onshore wind farms have increased from 15% to 25% in 2022. But, the cost competitiveness of RER has not been affected. This is because, the prices of fossil fuel, as well as electricity, have globally broken historic records. For instance, the power prices in some European countries such as Italy, France and Germany have reached more than six-fold compared to the mean price from 2016 and 2020 [28].

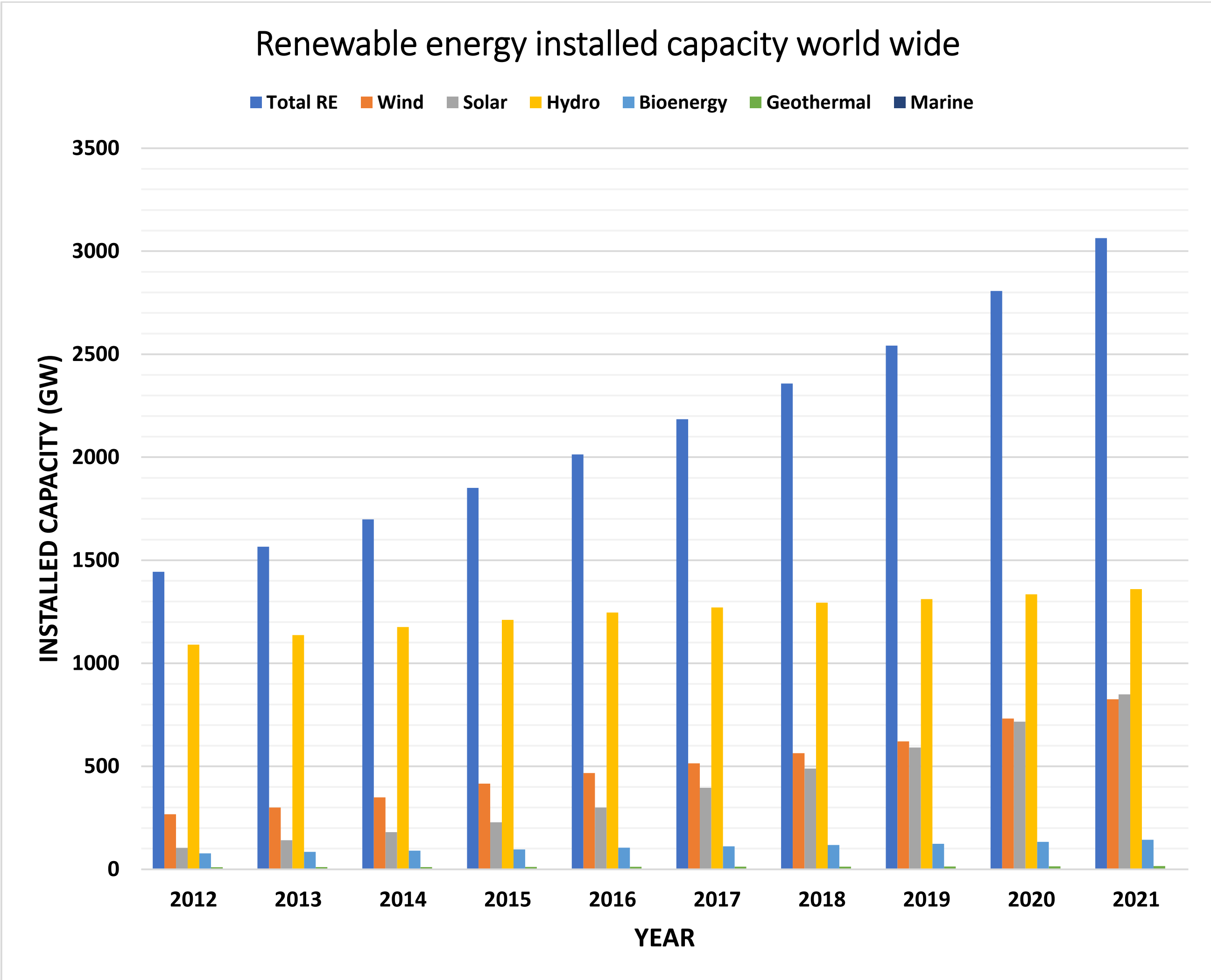

Figure 1. Total RER installed capacity during 2012–2021.

1.6. Green Investment and Economical Sustainability

The transition toward RE becomes an inevitable necessity. Massive investments need to be directed toward green and RE. The governmental sector could not afford this invoice alone. The private sector should bear some responsibility. Green investment markets are facing many difficulties. Firstly, green investment's meaning and goals must be accurately defined. Green investment includes private sector investment, job opportunities and added gross value and their social, economic and environmental effects. Green investment aims to achieve GDP per capita growth, the magnifying share of RE and GHG emission reduction which are the main goals of SD [29].

Anam et al. have studied the correlation between RER-based electricity consumption, economic growth and GHG emission in newly industrialized countries between 1990 and 2015. The obtained results revealed that, RER-based electricity consumption and economic growth are correlated in the short and long term. RER-based electricity consumption has a positive impact on GDP and GHG emissions in the long term. An one percent increase in RER-based electricity consumption led to a 0.095% increase in economic growth [30,31]. Another study has also studied the correlation between economic growth, GHG emission and different clean energy resources in the ten highest air-polluting countries. They discovered that, both RER and nuclear energy have higher contributions in reducing CO_2 and increasing economic growth compared to natural gas [32].

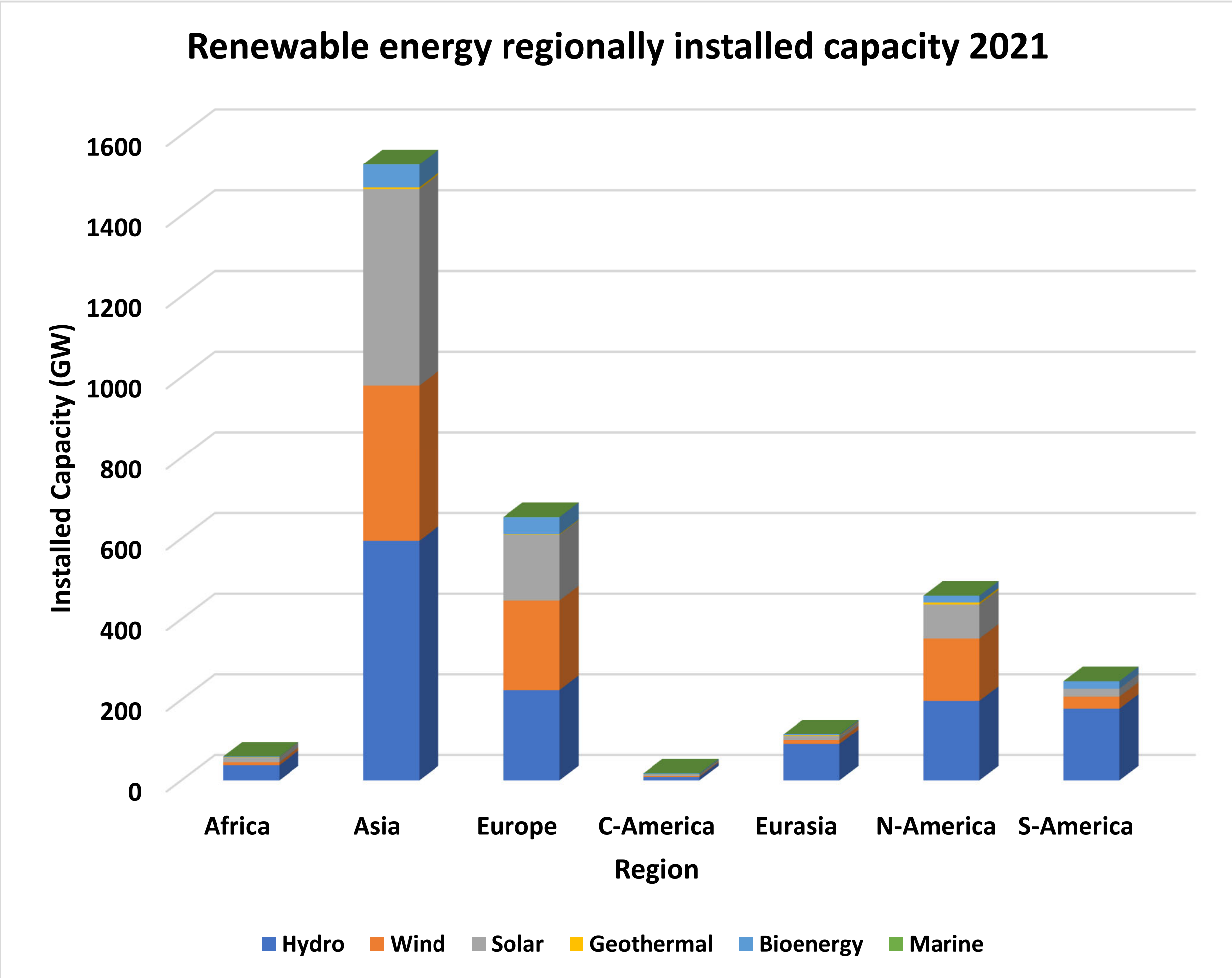

Figure 2. Different RER installed capacities according to regions.

Green investment is a long-term investment characterized by a long payback time, a low rate of return investment and it comprises many risks and uncertainties. Green projects include uncertainties through all stages of planning, structure and operation. Investment risks are a multi-dimension problem that depend mainly on the vision of investors. Investors are concerned with a safe investment with huge investment returns. On the other side policymakers plan to achieve government target by preparing effective policy plans. Both sides need to reach a medium point by defining these risks and accurately eliminating them. This would encourage investors, increase green investment growth and guarantee SD. The main risks include economic, technological, political, market, environmental and social risks. Eliminating these risks could be achieved through; openness and transparency policy; ensuring public acceptance; encouraging investors through preparing a suitable policy; providing sufficient knowledge about profitable green investment chances and encouraging financial institutions to support RE projects. This would increase foreign direct investment in RE projects. That would support SD and increase RE consumption in the long run [33–35]. In general, financial development has a negative environmental effect but RE financial investment has a positive effect on the environment and SD. As a result, global policymakers should provide low-interest loans for the private and public sectors by national banks; efficiently allocate investments to encourage green projects and reform policies for developing and developed countries to restrict projects that degrade the environment [36].

2. Research Methodology

Choosing a proper research method would achieve both validity and reliability. The main drive for this work was the desire to review the latest developments in the field of RE and the role of RER to attain SD. It started with reviewing the international reports IRENA (2022) [27] and IER (2022) [28]. Several observations have emerged. Firstly, the contribution of RER which includes hydropower to the total global energy consumption is still less than 30%. Secondly, hydropower has the main contribution followed by wind and solar energy which are expected to possess much more contribution in the future. Finally, biomass and geothermal energy have a small contribution with a promising future. As a result, this study focuses on wind, solar, biomass and geothermal energy which are expected to have a great contribution to the energy market.

At this time, Egypt is preparing to host the Climate Summit cop27. This event reflects the importance of RER as a source of clean energy. So, many papers have been reviewed using the skimming technique to figure out the relationship between RER and environmental health. However, RER are expected to be a clean energy source but they still have an environmental impact that varied based on plant size, location and technology. While skimming different review articles on the environmental impact of RER, the definition of life cycle assessment came out. As a result, LCA study has been added to this work.

Moving towards RER has become inevitable for sustainable development so, this study is a literature review focusing on RER technologies and life cycle assessment. This study has been prepared based on three main pillars which are; defining the purpose of the study; collecting data and selecting proper research.

2.1. Determining the Aim of the Study

The purpose of this research is to address renewable energy resources and their effects on sustainable development considering environmental impact. Also, life cycle assessments for all types has been studied in order to accurately evaluate environmental impact. Finally, RE-based electrical power plants have superiority other applications. Two main research questions have been prepared to achieve these objectives as follows:

Q1: What are the recent technological development in Wind, solar, biomass and geothermal energy? This research question aims to highlight recent technologies of energy sources under consideration, their efficiencies and their ability of implementation.

Q2: How to evaluate the environmental impact of RER under consideration using LCA, especially for power plants? This question aims to evaluate the environmental effects of different RER and how to reduce these effects to improve environmental conditions.

2.2. Data Collection

First of all, constructing the main framework for this research work. This framework consists of three main sections which are sustainable development, technological development of RER under consideration and life cycle assessment. Each section has been divided into subsections. A Keyword research framework that serves the objectives of this research has been applied to search for suitable papers linked to the topic under study published since 2018 as follows: "sustainable development", "renewable energy resources", "wind energy + technology", "wind turbine + technology", "solar energy + technology", "solar thermal energy+ technology", " solar photovoltaic energy + technology", "biomass energy + technology", "geothermal energy + technology", 'electricity', "life cycle assessment", "life cycle assessment + wind energy", "life cycle assessment + onshore wind energy", "life cycle assessment + offshore wind energy", "life cycle assessment + solar thermal energy", "life cycle assessment + solar photovoltaic energy", "life cycle assessment + biomass energy", "life cycle assessment + geothermal energy". Also searching for common acronyms such as RE, SD, RER, PV, GE, LCA, WT, and BE. This led to an enormous amount of research.

2.3. Selection Process

To prepare a convenient study, the selection of references has to be scrutinized and be careful. To be accepted as a reference, The collected papers have to meet some criteria as follows: peer-reviewed; directly linked to the point under study; written in English language, published from 2018, specified in electrical power generation and preferred to be cited. All papers that do not meet these criteria are excluded. The rest of the papers have been reviewed using the skimming technique considering the abstract, main frame and conclusion. After the potentially relevant articles were grouped, the full text has been reviewed for appropriateness based on their main focus. Finally, 2018 references have been included in this study.

2.4. Results and Discussion

Many reports, articles and reviews have been considered at the beginning of the study which includes 2560 papers. In the first stage, abstracts and conclusions have been checked for direct connection to the purpose of this review. As a result, 1176 papers have been rejected. The second step comprises a skimming process for the remaining papers. As a result, 831 papers that do not deal with electricity generation have been rejected. Finally, the scanning process has been applied to the remaining papers. As a result, 311 papers that do not have valuable contributions have been rejected. After these three steps, the number of papers under consideration is 242 papers. The pie chart that represents the paper rejection process is illustrated in Figure 3.

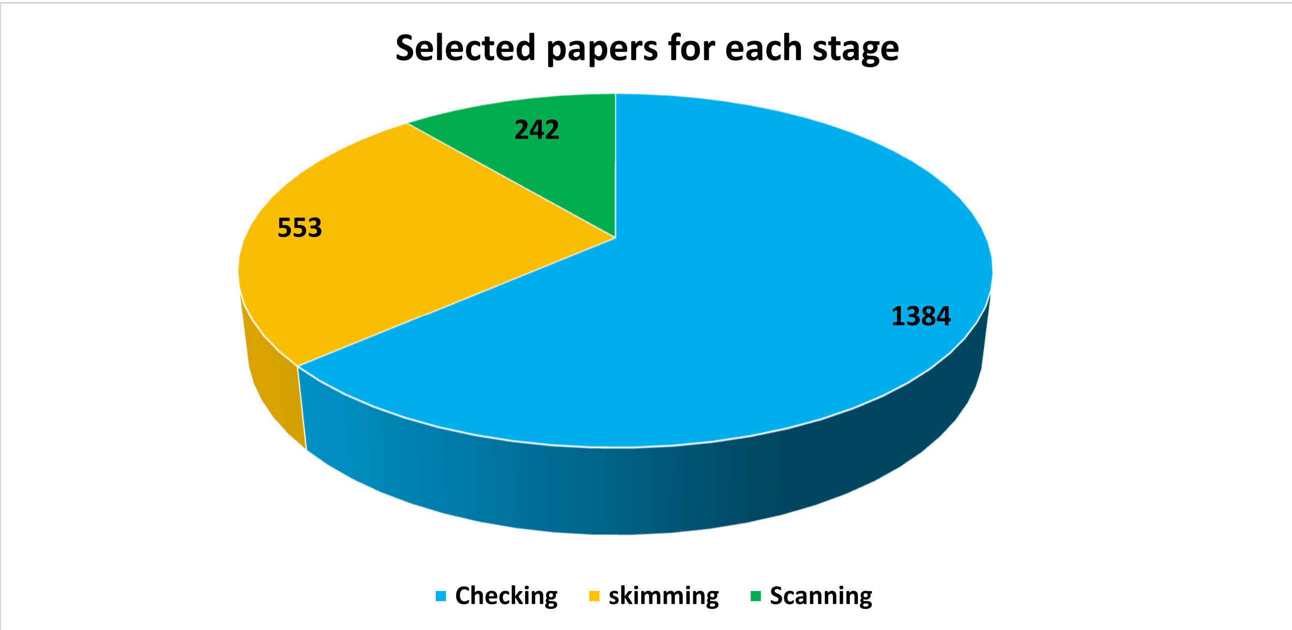

Figure 3. Research selection for each stage.

RER is a fertile research area. Many researchers have focused on different parts. Some studies have focused on RER's environmental impact such as [37]. Some have studied classifications, obstacles and solutions for supporting the development of RER such as [38]. Some others have studied how to develop RER to prevent predicted energy crises such as [39]. Many other researchers have studied one type of RER. For instance, in [40], the present WT technologies and obstructions towards their commercialization have been studied. Also, some solutions have been proposed. In [41], generating electricity based on hybridization between biomass and other RER has been studied while showing obstructions and designing parameters. Only two types of biomass energy have been proposed, gasification and anaerobic digestion. In [42] development of power plants based on geothermal energy has been studied. Also, challenges have been explained to be eliminated in order to develop these power plants. In [43], generating electricity based on geothermal wellhead technology has been studied temporarily during installation and permanently after finishing. LCA for wind, PV, BM and hydropower have been studied for electrical power generation based on environmental effects [44]. LCA of electricity generated from a wide capacity range WT has been studied based on environmental performance [45].

This research deals with the study of two basic elements to achieve sustainable development on the basis of the development of electric energy produced from four different types of RER which are wind, solar, biomass and geothermal. These elements are RER technological advancement and RER life cycle assessment which are directly connected to the aim of the paper. This study focuses on published papers during five years from 2018 to 2022. Other supporting areas of research have been reviewed such as: fossil fuels and their impacts on human health and environment; RER and economic sustainability; RER worldwide situation; challenges that obstacle RER developments and RER environmental effect.

There is no complete study prepared for any branch of science. Different studies complete each other. Although this paper has received a great effort, it was not enough to cover the main point adequately. This study is subjected to several limitations as follows:

- Comparing RER under consideration cannot be accurately applied except for some special cases because having the same rated power for different real power plants with the same network restrictions is hard to find. So, these resources cannot be calibrated to the same standard.
- Due to the enormous amount of research published since 2018, gathering all information about RER technologies and LCA is not fully achievable.
- Comparing LCA for different types is not satisfactory due to data scarcity, and missing suitable standards and methodologies.
- It would be better to handle only one type to receive an intensive care
- It would be better to extend the study to include ten years instead of five.

3. RER Technological Advancement

In this section, the proposed RER (Wind, solar, biomass and geothermal energy) have been studied based on the available technologies and the new emerging technologies. Energy conversion techniques also have been studied. Different applications have been introduced for each type to reveal the real effects of these technologies.

3.1. Wind Energy

The WE system has precede other types of RE systems. Also, it comes next behind hydropower energy. WE systems have been developed over years. Wind turbines are the most important parts of the WE system which have been developed over years. This is obvious through increasing size and capacity. Another indication is economically increasing generated power. Also, installation of WT in hard-to-install locations. The large growth of installed WE systems has led to more complex requirements for interconnection in order to enhance system stability [46]. The capacity of most wind turbines was 2 MW from 2005 till 2013 then, it has increased to 3/3.5 MW. Also, the tower’s height increased more than two times since 1990 to 100 m and more. The blade’s length and operating range (cut-in and cut-out) are not an exception, they both have increased [47]. The nacelle and tower have a great impact on a small-scale wind turbine [48]. The recent technological development in wind turbine manufacturing has led to increasing generation limits. The size of the unit has become 3.00 MW and higher. As a result, WE plays an important role in the electrical grid [49]. Large wind market earns much more strength due to governmental support while the small-scale market is still small. The growth of small-scale turbines depends on decreasing the installation cost and increasing governmental incentives [50].

Wind turbines could be classified based on the construction and orientation of the rotor shaft. WT is generally divided into two types, horizontal axis wind turbines (HAWT) and vertical axis wind turbines (VAWT). The main parts are the generator, rotor shaft, gearbox, blades and tower. Each type has its own structure and characteristics. In HAWT, the rotor shaft is aligned parallel to the wind direction. All parts are mounted on the upper part of the tower. On the other side, VAWT includes a rotor shaft perpendicular to the wind direction and attached to the turbine. The generator and gearbox are installed near the base of the tower. VAWT is divided into two types, drag-based turbine and lift-based turbine. The drag-based turbine is the simplest type. It rotates more in the same direction of wind and vice versa. The lift-based turbine is not self-starting so, it starts with a powered motor. HAWT includes two types, upwind and downwind types [51].

VAWT possess many advantages: It extracts energy from the air from any direction; it has noise much lower than HAWT; it works at low wind speed; it performs better than HAWT during turbulent wind flow; it needs a small area to be installed and is easy to maintain. All these advantages make it suitable for urban areas. VAWT required an effective control strategy to produce energy efficiently. Two control techniques are usually used for VAWT, fixed and variable pitch controllers. Variable pitch control technique is more efficient and self-starting under low-speed conditions [51]. Compared to HAWT, the VAWT provides better performance in tropical and windy climates [52]. VAWT are proper for unstable wind region. So, it has a positive and negative torque. In order to operate efficiently, a wind deflector is installed to enhance positive torque and eliminate negative torque. The deflector location and direction have been reviewed to enhance the generated power [53].

Due to its ability to work at low speed and more turbulent wind, VAWT has been studied for urban applications. It has shown a good performance, more safe and negligible noise [54]. The lift-type VAWT has been reviewed based on aerodynamic design parameters. Each parameter has been studied in order to reveal pros and cons [55]. Also, it has been reviewed for onshore and offshore applications. Offshore WT is much more suitable for today's design and capacities which exceeded 10 MW; the capacity of onshore WT could be increased through increasing towers and blades [46,56]. The available techniques for improving the performance of lift-type VAWT have been reviewed based on design, flow control methods, pitch controller techniques, blade style and supporting power devices [57]. VAWT has been studied for offshore applications considering multi-criteria to investigate whether it is suitable or not [58]. VAWT output power has been supported with a duct consisting of three parts a diffuser, a nozzle and a flange. As a result, the power coefficient has increased up to 2.9 times [59]. A wind flow modifier and an involute rotor have been proposed to enhance the maximum power coefficient for urban application [60].

Although VAWT has many advantages, it is not common such as HAWT which is suitable for large capacity and much more stable. Also, it has a large tower and taller blades. To be efficiently operated, HAWT's blades must be directed to face wind speed throughout a yaw mechanism. HAWT needs a special equipment to be installed, operated and maintained. Also, it produces more noise [51]. Large scale HAWT-based lift principle is economic, cost-effective, more efficient and much more reliable. The generated energy depends mainly on turbine capacity, hub height and rotor diameter [47]. Multi-megawatt HAWT is a growing developed technology. Improving system efficiency could be achieved through strategies. Increasing height is an effective strategy but it is limited due to structural aspects. So, designing blades have been proposed to make HAWT more efficient [61].

Small-scale HAWT design and development have been reviewed based on WT blades, diffusers, airfoil and adding winglets considering maximum power point tracking (MPPT) and environmental impact as illustrated in [62]. Also, it has been studied based on power coefficient and startup time by accurately selecting suitable airfoil [63]. The performance of small-scale HAWT has been investigated considering the effect of winglets based on power coefficient and thrust force coefficient. Different design and configuration of winglet has been studied intensively. When the winglet is exist, both power and thrust force coefficients would be increased [64]. Yaw control systems have been reviewed based on mechanical and aerodynamic pieces for large-scale HAWT. Yaw control systems could be classified based on their objectives into three types, maximizing generated power, reducing fatigue and maximizing extracted WE [65]. The yawing dynamic behavior of small-scale HAWT has been studied numerically and experimentally [66]. Unsteady Reynolds Averaged Navier-Stokes technique has been applied to study the aerodynamic characteristics of HAWT considering static and dynamic yawed conditions and start/stop yawing rotation [67].

Wind turbines also could be classified into two types, fixed and variable speed WT. Fixed speed WT consists of a squirrel cage generator connected to a multi-stage gearbox connected directly to the grid. It is simple, reliable, robust and cost-effective. It is low-performance WT characterized by fluctuating power, unstable voltage and stressed mechanically at high capacity. It is suitable for generating a capacity below 1.5 MW. Variable-speed WT consists of WT connected to the generator through a gearbox which is connected to the grid through power converters. It is characterized by, reduced mechanical stress, controllable output power, higher efficiency, improved power quality and a reduced noise level. It is suitable for higher-rated power (1.5–5 MW). Three types of generators have been used, Doubly-Fed Induction Generator (DFIG), Fixed speed Induction Generators (FSIG) and Synchronous Generators (SG). Also, to increase efficiency, MPPT techniques have to be considered [68].

Operation and maintenance costs of the current WE system are 20–25% of the total levelised cost of electricity. So, it has recently received more attention. Researchers recently pay attention towards failure analysis to minimize the probable fault occurrence which requires complex and costly maintenance [69]. People's opinion always affects the success of any project or idea. Lack of public awareness of environmental problems and climate change may be a serious obstruction in promoting RE. For instance, SE are much accepted for cooking, water heating, and food drying but, still have less acceptance for electricity generation. Increasing awareness of RE's importance would enhance the future of RE [70].

According to the former collected data, great efforts have been directed toward increasing WE system capacity, and efficiency and improving system performance. This could be achieved through: improving the design of towers, blades and gearboxes; enhancing the available control techniques such as yaw control mechanisms and MPPT techniques; improving Operation and maintenance systems through analyzing failures and faults; seeking for effective solutions to reduce manufacturing and installation costs and comparing between available WT technologies based on adequacy for different applications such as onshore, offshore and land-based.

3.1.1. Environmental Impacts of Wind Energy

WE system causes many environmental impacts such as noise impact, visual impact, bird death, deforestation, lightning hit towers and electromagnetic interference. These impacts and proposed solutions are illustrated in Table 1 [71–76].

Table 1. wind energy environmental impact and solutions.

Environmental Effect	Solution
Noise comes from interactions between turbine blades and speedy wind also the rotating mechanical parts of generator, cooling fan and gearbox which would increase for a larger turbine and higher wind speed. Also noise from construction and installation	Installing wind farms away from inhabited areas
Visual impacts come from wind turbine shape, size, shadow flickering and distance from populated areas	Designing wind turbines in harmony with surrounding
Bird's death due to collisions between birds and turbine blades and this is very small compared to bird's death from other human activities also changing the original habitat of birds	Accurately chose the site of wind turbine considering wildlife safety

Table 1. *Cont.*

Environmental Effect	Solution
Electromagnetic waves generated from wind turbine cause interference with nearby other electromagnetic devices such as radio, TV, communication systems and microwave	Installing wind turbines away from populated areas and radio and TV broadcast stations
Deforestation due to removing plants and vegetation during construction, transportation, installation and connection to utility grid	Proper design, planning and execution of WT projects in order to reduce deforestation.
Large-scale wind turbines could change region heat by warming at night and cooling during daylight	This impact is under study and requires more research
Offshore wind turbines required submarine cables which may cause chemical pollution and affect the marine creatures	Proper design, selection and installation of submarine cables

3.1.2. Challenges Prevent Development of Wind Energy

Wind power emerging technologies have been studied for development achievement in the future. Based on experts' views, there are many obstacles that need to be eliminated such as [77]:

1. Providing durable, lightweight and cheap manufacturing materials;
2. Enabling developed control strategies;
3. Providing developed substitution support structure;
4. Providing a smaller energy extracting devices;
5. Providing advanced power transmission techniques;
6. Investments and funds for research and wind energy projects.

3.2. Solar Energy

The SE transmitted to earth is incredibly large. PV cell is used to absorb the photon energy in solar radiation and convert it into electricity. The main objective of technological development is to provide both economic and efficient energy sources. PV systems are divided into three generations. The first generation consists mainly of single-crystalline and multi-crystalline silicon. The second generation consists mainly of thin-film PV cells which comprise amorphous silicon, cadmium sulfide (CDS) and cadmium telluride (CDTe). The third generation comprises other silicon-free technologies such as perovskite PV cells, dye-sensitized PV cells and quantum dot PV cells [78]. This new technology is facing many challenges such as, sociotechnical barriers due to the missing data for most people which causes inappropriate use and maintenance; Management barriers due to improper financial strategy and bad after-marketing services and economic barriers due to high cost, especially for the installation. So, people moving towards the conventional source of energy and policy barriers due to missing or ineffective policies [79]. PV cells must meet some requirements in order to be commonly used, cost-effective, high efficiency, long life cycle and have available constructing materials. Crystalline-based PV cell fulfils all these requirements [80].

Bifacial PV technology is a new trend in PV solar cells. It has appeared on the scene strongly. It is expected to share in the PV market with more than 35% by 2028. Bifacial PV cell has many advantages. It absorbs solar radiation from both sides which increases the generated power. The power losses due to aluminum base removal would be eliminated. Also, it protects the cell from being bending because silicon and aluminum have different thermal expansion [81]. Bifacial crystalline PV cell technology superiors conventional PV cell technology as illustrated by authors in [82]. Bifacial PV technology field study starts in 2009. However, the available researches are quite limited. It faces some difficulties such as complex mechanisms and non-uniform rear-side irradiance. The main difference between mono-facial and bifacial PV technology is, the back surface of the PV cell. In mono-facial it contains a back surface field while in bifacial it contains antireflection coating and electrical contacts. So, bifacial PV cells could extract radiation from both sides [83]. Bifacial PV technologies could be divided into six types as follows: passivated emitter rear contact [84–86], passivated emitter rear locally-diffused (PERL) [87–90], passivated emitter rear totally diffused [91–93], heterojunction with intrinsic thin-layer (HIT) [94–97], interdigitated back contact [98–100] and double-sided buried contact solar cell [101].

Another new emerging technology in PV cells is Hollow semiconductor photocatalysts. This strategy helps the cell to use light efficiently. Presently, researchers focused on the composition of oxides, nitrides, sulfides and organic semiconductors to produce high photocatalytic materials [102]. Hollow Nanostructures for Photocatalysis-based PV cells have a promising future. It provides more energy with negligible environmental effects. Photocatalysis process includes three steps, light absorption then charge splitting and transfer and finally surface reaction. The hollow nanostructure has many advantages such as, increasing light utilization through light diffusion and slow photon effects; deactivation of charge integration through decreasing charge transition distance and separation of charge carriers, and speeding up surface reactions through increasing surface area and discrimination between redox reactions. Hollow Nanostructures based Photocatalysis experience many challenges such as, Limited application, complex manufacturing process, new unclarified technology and industrial difficulties in providing large pure crystalline surface area [103]. However, this technology is new but some interesting researchers have applied this technology successfully [104–107].

An organic solar cell is an emerging technology based on organic semiconductor materials. It has two advantages over inorganic types, manufacturing cost-effective and ease of implementation on flexible substrates. The highest recent energy conversion efficiency obtained by organic, quantum dot, flexible SCs, compound semiconductor-based solar cells, DSSCs, perovskite and silicon PV cells is 13.76%, 18.05%, 15.38%,53.8%, 12.3%, 25.2% and 27.6% respectively [108].

According to the former collected data, many technologies have been studied to provide better performances and higher efficiencies. Silicon-based PV cells still dominated other technologies. Both thin film and silicon-free technologies receive considerable attention as cheap alternatives for silicon PV cells. New emerging technologies have been studied for years such as bifacial, hollow conductors and organic PV cells in order to be effectively used in future. These techniques however being applied successfully in producing electricity are still under research. The conversion efficiency is highest for silicon PV cells and lowest for organic solar cells.

3.2.1. Environmental Impact of Solar Power Plants

The solar PV power plant has a negligible environmental effect except for large-scale power plants. Most environmental concerns are resultant from the manufacturing process, especially heavy materials such as steel, iron, copper, silicon and aluminum which require intensive energy. For Solar TH power plants, both manufacturing and operation have the same environmental effect [109]. The environmental impacts could be summarized in Table 2 [110,111].

Table 2. Solar power system environmental effect and solutions.

Environmental Effect	Explanation	Solution
Impact on biodiversity	Spreading solar power plants, especially of large-scale PV type would remove vegetation; sometimes would prevent animals' migrations;	Accurately chose the site of solar system considering wildlife safety
Electromagnetic interfering	Transmission lines produce electromagnetic radiation which threatens the life of living species.	Installing solar system away from populated area and radio and TV broadcast stations
Water consumption	Solar thermal systems (STS) consume a large amount of water while PV systems use a small amount of water. Sometimes this would reduce the water available for vegetation and drinking for living.	Could be avoided by using a closed-loop water system and using smart washing systems.
Impact on land-use	Compared to other types of renewable energies, solar power plants especially PV systems require a large area of land to be operated and maintained.	Could not be avoided but it would be better to choose remote areas to install such power plants.
Visual impacts	The effect is linked to the nature of the surrounding areas. When the solar system is installed near beautiful nature views or historical places it would distort the view. Also, the glare resulting from reflected radiations would be uncomfortable for sight.	Designing wind turbines in harmony with surrounding
Health and Safety	PV cells sometimes use toxic materials in manufacturing and maintenance. Also, in concentrated solar plants of large scale such as wet-cooled plants, some toxic materials are used. These toxic materials would badly affect human health.	Installing wind farms away from inhabited areas

3.2.2. Challenges Facing Solar Energy Developments

Obtaining maximum benefits from solar power plants requires determining all barriers in order to be eliminated. Solar power plants, similar to all other RER, face many challenges such as [112]:

1. Technological barriers linked to manufacturing, operation and maintenance
2. Transparency and accountability barriers linked to corruption, lack of accountability and lack of transparency
3. COVID-19 pandemic barriers which delay the installation of many plants and disrupt the development process
4. Financial barriers linked to the ability to provide financial funds for development
5. Policy and regulatory barriers linked to energy prices, feed-in tariffs and restrictions
6. Infrastructure related to unsuitable power plant construction that would face many problems when integrating solar systems.

3.3. Biomass Energy

Biomass energy (BME) is one of the most confusing sources of energy according to most people. They either have no idea about the working mechanism or correlating with combustion such as conventional energy sources. It is the main source of nutrition and energy for human beings and all living creatures. BME required proper employment to be economic and clean energy with zero carbon dioxide. Biomass as a word consists of two parts bio which refers to animals and mass which refers to plants. Biomass is a carbon-neutral source of energy as the amount of carbon dioxide consumed during the photosynthesis process is the same as that released during incineration. Also, it does not produce other GHG emissions such as methane and nitrogen dioxide [113]. Biomass fuels contribute 10–14 of total consumed energy, 40% of energy production in urban areas and 90% of energy production in rural areas. Biomass is converted to different forms of energy such as electricity, thermal and transportation fuels. Various types of biofuels are produced from biomass such as bioethanol, biodiesel, biogas, bio-butanol, bio-oil and bio-hydrogen [114]. Biomass is available in three basic forms of the substance: Solid, liquid and gaseous, which in turn can be divided into primary materials and by-products [115].

Expanding the use of clean BME such as biofuels and biogas improves ecological health and accelerates human development. However, the conventional use of BME causes an adverse impact. Proper utilization of biomass is linked to technological advancement. As a result, governments should encourage investments, direct institutional researches, and regulate policies toward BME. This is to enhance biomass technological developments in order to minimize installation and running costs. For investors, site selection is a crucial issue to reduce transportation costs and guaranteed abundant sources of biomass. This would improve the BME sector and reduce GHG emissions [116–118].

Biomass is classified according to the type of vegetation and applications and there are many classifications. For instance, classifications of biomass based on types of vegetation include woody, herbaceous, animal and human waste, aquatic and mixtures [119]. Woody biomass includes barks and leaves of trees both over and underground and residue of trees and roots [120–124]. Herbaceous biomass is a non-woody stem plant such as agricultural waste and energy crops [125–130]. Animal and human waste biomass such as human dung, animal manure, flesh and bones are converted to fertilizers used in agriculture or converted to biogas [131–133]. Aquatic biomass comprises microalgae, macroalgae and plants that grow partially submerged in swamps [134–139]. Biomass mixtures are a combination of two or more substances from the former types [140–144].

Biomass is difficult to use in its primary form, so it is converted into another form of energy. The commonly used biomass conversion techniques are Thermochemical, biochemical and physicochemical [119]. Thermochemical conversion comprises both thermal and chemical processing and is divided into four processes such as Combustion, Pyrolysis, Gasification and Liquefaction. The combustion process is the fusing of biomass with oxygen in a high-temperature medium. This process produces heat, carbon dioxide, and water vapor. This process accounts for about 90% of the total energy provided by biomass. The pyrolysis process mainly aims to convert biomass into solid charcoal, liquid bio-oil, and gaseous combustible gas through partial combustion at different temperatures. This process includes drying, distillation, exothermic reactions and evaporation. Gasification means converting solid biomass into synthesis gas (syngas). Synthesis gas is used to generate electricity and is a basic material for the petrochemical and refining industries. Liquefaction means converting biomass into a liquid biogranulate. This process is performed in water under temperatures of 280–370 °C [119,145–154].

The biochemical conversion process uses biological species such as bacteria to break down biomass into simpler carbohydrates to convert into liquid fuels and biogas. Anaerobic digestion and fermentation are the most common biochemical conversion type. Anaerobic digestion is a biological process used to produce RE and used for waste management. The fermentation process is a series of biochemical reactions used to convert simple sugars into ethanol and CO_2 using microorganisms such as yeasts [119,155–161]. The physicochemical process is used to produce high-density biofuel (biodiesel) from biomass such as vegetable oils and animal fats under the esterification process [119,162–165].

According to the former collected data, most developments in the BME system are correlated to energy conversion techniques. Energy conversion techniques such as thermochemical, biochemical and physicochemical, are essential to utilize BME. Thermochemical processes especially combustion processes dominated other techniques. Biochemical and Physicochemical processes received considerable research efforts which have produced a powerful energy sources such as ethanol and biofuel which are used to generate electricity through combustion.

3.3.1. Environmental Impact on Biomass Energy

BME has many forms. Each type has different environmental effects based on nature construction and the surrounding area. These impacts can be illustrated in Table 3 [71,76,166].

Table 3. Biomass environmental effect and explanations.

Environmental Effect	Explanations
exhaustive exploitation of soil resources	- Terrestrial Acidification - soil erosion due to deforestation to plant crops - soil nutrients exhaustion - Changes in soil organic carbon - excessive use of pesticides and fertilizer
exhaustive exploitation of water resources	- Freshwater Eutrophication - Marine Eutrophication - Retarding groundwater recharge - Water pollution due to excessive use of pesticides and fertilizers
biodiversity reduction and starvation	- extending crops planting - reduction of forest area - increase hunger by Conversion of food into fuel - Changes in crop types
Air pollution	- Fine Particulate Matter Formation - Ozone Formation - Emitted toxic gaseous - Crop residue burning
Global Warming	- Incineration and other processes - Emitted GHG

3.3.2. Challenges Facing Biomass Development

BME did not receive enough attention. This may be due to many barriers such as [167]:

1. Investment risks due to uncertainty caused insufficient funds.
2. Energy/space efficiency is very low.
3. Transportation cost is very high.
4. Skilled labor is not available.
5. Research and development receive insufficient fund.
6. Public awareness is very low; conversion technology is costly.
7. Governments' policies are insufficient or ineffective.

3.4. Geothermal Energy

Geothermal energy (GTE) is an independent constant abundant energy resource. It provides a big share for power in Iceland (27%) and El Salvador (26%). It is an emerging RER extracted from earth's internal heat which comes mainly from molten magma and radioactive elements decay process. It can be categorized into shallow GTE, underground thermal water and hot dry rock resources. Shallow surface GTE is a low temperature concentrated in soil, gravel and water beneath within 200 m depth below the surface. Underground thermal water of temperature higher 25 °C within depth less than 4000 m. Hot dry rock resources is of temperature more than 150 °C buried within depth range 3–10 km [168]. GTE applied mainly for two purposes which are, electricity generation and heat production. It is expected for GTE to contribute 2–3% of total electricity generation by 2050 [169].

Working principle for geothermal power plant: extracting earth's internal thermal energy through injecting hydrothermal fluid such as water, this hot water produce pressurized steam that rotate the turbine which connected to generators. Three common power plants are used: dry steam, flash steam and binary cycle. In dry steam power plant, a hydrothermal fluid injected deep in earth to acquire thermal energy. Then it converted to steam used to rotate turbine to generate electricity. Then the steam would be condensed and injected again to the well. Flash steam power plant comprises the same former process except that, the lifted steam directed to a steam separator filled with high temperature hydrothermal fluid which converted to steam and separated. This separated steam used to rotate the turbine. This plant requires temperature more than 182 °C to be operated. In Binary cycle power, the extracted heat is transferred to another lower boiling point hydrothermal fluid converting it to steam directed to rotate the turbine to generate electricity [170].

Five technologies have been utilized to convert bio thermal energy into electricity. These power plants are dry steam, single and double steam, binary cycle and other advanced conversion systems which comprises hybridization between different technologies [171]. GTE can be applied directly in many applications. For instance, it could be used for heat pumps, Space heating and thermal Industrial processes. Also it can be used for drying crops and Greenhouses. For residential applications it could be used for space heating and cooling; Bathing and swimming and snow melting [172]. Heating and cooling of residential buildings has received more attention. New technologies have been developed to reach deeper layers to obtain higher thermal energy. Another direction towards utilizing lower temperature at smaller depth has been appeared to reduce heat losses and contaminated substances passes to the system [173]. Applying GTE to produce hydrogen is a promising field of research. Producing hydrogen based on geothermal power plant has been investigated considering thermodynamic analysis, techno-economic analysis and environmental effects [174]. Different geothermal power plants have been compared to select an efficient technology to produce hydrogen. Flash-steam combined cycle and binary cycle show better efficiency [175].

To obtain sufficient temperatures for large projects, more depth are required. Utilization of deep GTE required some advanced techniques such as hot dry rock (HDR), U-tube single-well, open loop single-well and closed loop single-well [176]. Enhanced geothermal power plant is a very common plant utilize the hot deep dry rock of temperature 120 °C to 220 °C to utilize GTE efficiently. The working principle comprises transferring the heat concentrated in hot dry rock to the injected water which converted into steam to generate electricity. The discharge fluid is injected again forming a circulating loop [177]. Strategies and Barriers for installing enhanced GTE plants has been introduced by the authors [178–180]. GTE not concentrated only inside soil, underground water, and deep hot rock but, hydrocarbon reservoirs also contains GTE [181]. As a result oil fields GTE has recently attracts many researchers [182–186].

According to the former collected data: GTE systems available data are still scarce and requires more research efforts; GTE is costly and dangerous; applications of GTE for electricity generation are concentrated in developed countries due to having special advanced technologies; Oil fields recently received a considerable attention as a source of GTE to produce electricity in oil field sites and the expected contribution of GTE in electricity generation could not exceed 3% by 2050. It would be better to concentrate on other RER systems.

3.4.1. Environmental Impact of Geothermal Energy

According to environmental effect, GTE is not a preferred energy source compared to other RE systems. But it is still an environment friendly source compared to conventional fossil fuels energy. GTE comprises different environmental impacts. There are surface and subsurface environmental effect, hydrological effect, geological effect, microbiological effect and air environmental effect. These environmental effects are illustrated by Table 4 [71,76,187–189].

Table 4. Geothermal power plant environmental effect and explanations.

Environmental Effects	Causes
Air pollution	- Unpleasant smell due to hydrogen sulfide - GHG emissions
Exhaustive exploitation and pollution of water resources	- Excessive used of water - The extracted water is contaminated with carbonate, sulfate and silica salts from operation and soil respectively - Underground water contamination with arsenic, lead and fluorin. - Groundwater depletion
Exhaustive exploitation of soil	- Earth landing Due to hot water/steam outflow from geothermal plant and soil response to injected fluid; - Surface disturbance resulting from constructing and operating - Induced landslip and earthquake activity due to pressure variation of circulating fluid in the geothermal field - Change of soil composition due to material extracted and material injected during operation
Biodiversity reduction	- changing natural environment that Impacts on habitats - obstacle moving of wild animals
Noise	- machines and equipment during construction and operation
Thermal pollution	- waste heat accompanied with wastewater released to environment; - Hydrothermal eruptions - Degradation of thermal features
Visual impact	- Distortion of view due to constructions and installations

3.4.2. Barriers Affecting Utilization of Geothermal Energy

Utilization of GTE is facing many obstacles as follows [190]:

1. Geological risk such as seismicity; land drop, landslip related to fluid circulation and decreasing water level
2. Noise resultant from drilling
3. Underwater pollution
4. High investment cost due to discovering, construction equipment and drilling cost and threating public health and safety.

3.5. Comparing between Environmental Impact for Different RER under Considerations

According to the preceding data, a comparison between environmental effect for wind, solar, biomass and geothermal RER could be held. This comparison is illustrated by Table 5.

Table 5. Environmental effects comparison for Wind, Solar, Biomass and Geothermal RER.

Aspect/RER	Wind	Solar	Biomass	Geothermal
Biodiversity reduction and human health	- deforestation during construction, transportation, installation and connection to utility grid - bird's death due to collisions between birds and turbine blades - changing the original habitat of birds	- remove vegetation for large scale PV - large scale PV prevent animals' migrations - toxic materials are used in manufacturing and maintenance. - toxic materials are used for concentrated solar plants of large scale such as wet-cooled plant.	- extending crops planting reduces forest area - increase hunger by Conversion of food into fuel - Changes in crop types	- changing natural environment that Impacts on habitats
Air pollution			- Fine Particulate MatterFormation - Ozone Formation - Emitted toxic gaseous - Crop residue burning	- Unpleasant smell due to hydrogen sulfide - GHG emissions
exploitation of soil		- solar power plants especially PV systems require a large area of land to be operated and maintained.	- Terrestrial Acidification - soil erosion due to deforestation to plant crops - soil nutrients exhaustion - Changes in soil organic carbon - excessive use of pesticides and fertilizer	- Earth landing - Surface disturbance - Induced landslip and earthquake activities - Change of soil composition
Exhaustive exploitation and pollution of water resources	- Offshore wind turbine required submarine cable which may cause chemical pollution and affect the marine creatures	- solar thermal system (STS) consume a large amount of water while PV systems use a small amount of water	- Freshwater Eutrophication - Marine Eutrophication - Retarding groundwater recharge - Water pollution due to excessive use of pesticides and fertilizers	- Excessive used of water - surface water contamination with carbonate, sulfate and silica salts - Underground water contamination with arsenic, lead and fluorin. - Groundwater depletion

Table 5. *Cont.*

Aspect/RER	Wind	Solar	Biomass	Geothermal
Noise	- Noise comes from interactions between turbine blades and speedy wind - the rotating mechanical parts off generator, cooling fan and gearbox - noise from construction and installation			- machines and equipment during construction and operation.
Thermal pollution	- Large-scale wind turbine could change region heat by warming at night and cooling during daylight		- Incineration and other processes - Emitted GHG	- waste heat accompanied with wastewater. - Hydrothermal eruptions - Degradation of thermal features
Visual impact	- visual impacts comes from wind turbine shape, size, shadow flickering and distance from populated areas	- Distortion of beautiful nature views and historical places - The glare resultant from reflected radiations		- Distortion of view due to constructions and installations
Other effects	- electromagnetic waves generated from wind turbine cause interference with nearby other electromagnetic devices such as radio, TV, communication systems and microwave	- Electromagnetic waves resulting from transmission lines which cause interference with nearby other electromagnetic devices such as radio, TV, communication systems and microwave		

According to Table 5, solar and wind RER have the least environmental impact compared to biomass and geothermal RER. Geothermal RER has the worst environmental effect and surrounding by many risks and hazards. Biomass energy environmental impact depends on conversion methods. Most of these environmental effects could be treated in future if there is a true will.

4. Life Cycle Assessment

Life cycle assessment (LCA) is a comprehensive technique used to evaluate environmental impacts during the life cycle of a product (cradle-to-grave). The life cycle includes obtaining raw materials, manufacturing process, working time and disposition or recycling. LCA is used to support the decision-making process to achieve SD by using the most effective solution. It uses to track materials, processes, and working time to reduce environmental impact. LCA is a systematic technique consisting of four phases as follows: defining the goal and scope of the study; analyzing inventory; impact assessment and interpretation. Firstly, determine goals, limits of assessment assumptions, and functional units. Secondly, gathering information on systems related to the power plant, environment, emissions, and location. Thirdly, evaluating LCA correlating to each impact category. Finally, explaining the obtained results, evaluating data quality, clarifying limitations and applying sensitivity analyses [191,192]. Current studies of LCA seem to be contradictory, which demonstrates limitations. Variation in results comes from dissimilarities in systems under study. Also, missing data, assumptions and methodologies may be the reason. But these differences may be an advantage in the future by providing more data. These data describe the system, methodologies, assumptions and surroundings. As a result, a great inventory build-up of knowledge is available for decision-makers. This would reduce efforts and improve the analysis of LCA [193].

LCA is subjected to data scarcity which affects the accuracy. Providing the required data for analysis, accurate studying of products' environmental impact, modelling of grid interaction based on optimization techniques and integration with geospatial techniques would improve LCA accuracy [194]. LCA has been introduced to address the environmental effect of photovoltaic, biomass, wind and hydropower plants. The results reveal that hydropower plants are much more environment-friendly compared to other systems. Solar and wind power plants cause a medium effect while biomass power plant has the highest damaging effect. A database is required for each type of RE plant to determine the most damaging elements to replace [44].

Large-scale hydropower plants have a lower environmentally damaging effect followed by small-scale reservoirs then run-of-river hydropower comes last with the highest damaging effect. But summer smug and global warming potential (GWP) is higher for large hydropower plants. Onshore wind power plant has a higher environmental impact compared to hydropower and geothermal but with the lowest GWP. The geothermal power plant has the highest acidification impact [195]. LCA of onshore and offshore wind power plants for electricity generation has been studied. LCA for electricity generation of a small-rated wind turbine is proportional to wind speed. But for large-scale wind turbines, the environmental impact is minor. Different environmental indicators, and innovative technologies need to be considered for future studies [45].

Environmental LCA performance has been studied for both types of solar systems (PV and thermal) based on different indices. Both thermal and PV solar systems could be very efficient in high average insolation areas when utilizing proper elements. Many systems have been proposed to supply buildings with thermal and electrical needs. For instance, two solar systems have been used to supply a social housing building with heated water and electricity based on LCA and energy demand. The first system is a water heater includes a collector and storage tank. The second system is a hybrid PV/thermal unit. The solar devices are integrated into the frontispiece of the building [196]. Another example, LCA for building integrated PV systems has been studied based on thermal, electrical optical and energy performance [197]. Also, the environmental LCA has studied mono crystalline

PV systems and evacuated glass tube collector STS based on 16 impact indicators. SPH system has a higher environmental impact compared to STS. Both systems could provide better environmental performance by proper selection of system elements [198]. The final example, the environmental LCA has been studied for two types of solar systems for residential applications. Type I are a thin film and crystalline SPH system. Type II are flat plate and vacuum tube STS [199].

4.1. LCA for Thermal Solar System

The thermal solar system is an effective method for reducing GHG emissions and improving the environment. LCA environmental impact has been studied for different thermal systems considering different objects. For example, LCA uncertainty analysis and techno-economic evaluation are considered for water heating roof-mounted STS for a family house. This study considers heating needs, LCA, cost and energy. STS could be very efficient even at low fee-in-tariff in high average insolation areas [200]. Another example is the environmental performance of LCA of industrial STS has been studied considering potential of carbon savings according to European Union Emission Trading system [201]. Final example, the environmental LCA has been studied for electricity generation from STS considering global warming impact and energy payback time [202].

4.2. LCA for PV Solar System

PV solar system is an environment-friendly power system. There are many types of PV modules such as mono and Polycrystalline, thin film, perovskite, and dye-sensitized PV cells. Environmental impacts for all these types are acceptable but not equal. For instance, the grid-connected PV power plant has been reviewed based on LCA for the environmental impact of generated energy. Both silicon and non-silicon-based PV technologies have been analyzed to provide information for future analysis [203]. Another example, the end-of-life LCA environmental impacts of silicon PV modules have been studied. Four cases have been considered, reuse, landfill, incineration, and recycling. Recycling options include chemical, mechanical and thermal. PV module waste management has been studied to achieve the best environmental benefits [204]. Also, the LCA environmental performance of grid-connected and ground-mounted polycrystalline PV systems has been studied based on payback time [205]. As another example, the LCA environmental impact of different PV technologies has been studied based on energy payback, GHG emission and cumulative energy demand. The obtained results of the studied PV solar systems (silicon, perovskite, dye-sensitized and thin film) reveal that the mono crystalline type has the worst LCA environmental impact. It is characterized by long payback time, higher GHG emissions and higher energy consumption [206]. LCA environmental performance of an electric propulsion ship supplied by a PV system as a future energy solution for marine transportation has been studied based on different operational and environmental conditions [207]. The building LCA methodologies, barriers and drivers have been reviewed based on environmental impact [208].

4.3. LCA for Land-Based Wind Turbine

A wind turbine has an average lifetime of 20–25 years, then it would be disposed of. Nowadays, large-scale WTs become more common, especially for offshore WT. most environmental effect of WT comes from the manufacturing process which is 70–80%. Recycling methods are convenient for most constructed materials. This would secure many resources for the future and improve environmental health [209]. Recycling materials have a 30% reduction in environmental impacts. Although drag force-driven WT is heavier compared to lift-driven turbines it is suitable for using easily recyclable material. LCA environmental impact for drag force-driven WT-based recycling has been studied considering eleven environmental indicators [210]. The environmental effects of hydro, nuclear and wind power plants have been studied during the whole life cycle considering manufacturing, erection, operation and disposal at the end of life. LCA includes GWP, acidification, human toxicity and ozone production. Wind power plants produce lower environmental impact followed by nuclear and hydropower plants. The manufacturing process for wind and hydropower plant have the highest impact but for a nuclear plant, waste management has the most significant impact [211]. LCA has been studied for disposal blades in Ireland to reduce environmental impact. Three methods have been proposed, co-processing in cement production in Germany, co-processing in Ireland (future studies) and landfill in Ireland [212]. The authors have studied the LCA environmental impacts of a small-scale vertical axis WT based on eleven environmental indices. Also, the benefits of developing such a system are to reduce environmental impact. This study has been applied for the whole LCA and for the end of life. The obtained results show a very poor performance due to low wind speed [213].

4.4. LCA for Onshore Wind Turbine

Most environmental effect for onshore WT comes from manufacturing and waste management without any emissions during work life. Three types of onshore wind turbines are commonly installed to generate electricity, geared-converter doubly-fed induction generators and both permanent magnet and electrically excited direct-drive synchronous generators. LCA environmental effects have been compared for the former three types [214]. LCA environmental impact has been studied for onshore, shallow-water and deep-water considering material processing and payback time [215]. LCA environmental performance has been studied for onshore 185 m hybrid towers considering the manufacturing process, installation and transportation [216]. LCA for onshore and offshore wind turbines has been studied for GHG emissions during the whole life cycle [217]. Onshore wind turbine LCA for GHG emissions has been studied and compared to fossil fuels-based power plants. Also, the effect of increasing and decreasing turbine rates has been studied [218]. The environmental performance of LCA for two different onshore wind turbines has been studied during the whole life cycle for GHG emission. Also, a sensitivity analysis has been applied to investigate the effect of wind speed variation [219].

4.5. LCA for Offshore Windturbine

An offshore wind turbine LCA environmental impacts have been studied based on contaminant materials and manufacturing energy consumption. Offshore wind turbines are usually constructed from steel, iron, concrete, and petroleum-based material which has a great environmental effect and consumes so much energy in manufacturing [220]. An offshore wind turbine LCA has been studied for global warming potential (GWP) based on maintenance and operation during the whole life cycle. This would help the decision maker to select proper design, operation and maintenance strategies [221]. LCA environmental impact for 20 offshore wind turbines has been studied based on installation considering eleven impact, GWP, resources consumption, human and eco toxicities and others [222]. Environmental impacts of a land-based and offshore wind turbine have been compared based on four indices, non-ergonomic, non-functional, non-ecological and non-sociological to investigate effects on the environment, human health and natural resources [223]. The authors have used green cement for foundations and locally manufactured turbine to reduce environmental impact to improve LCA's environmental impact. This has caused a reduction in GHG emissions and payback time [224].

4.6. LCA for Geothermal

Geothermal energy is a unique RE source for both thermal and electrical power. It is not affected by climate conditions. Also, it provides stable output suitable for most the energy consumption. Although it produces GHG and toxic emissions throughout construction, development and operation of the power plant, the major environmental effect comes from direct emission to the atmosphere during the operational phase (84%). The environmental impact is varied based on plant size, location and technology. LCA is an adequate method to compare geothermal plants to other plants. Also, it is comparable to other RER but actually, it is very small compared to energy mixes [225,226]. Geological hazards, land use, GHG and water are not sustained constantly they may change with time. LCA of geothermal power plant studies is rare and site-specific due to varying nature and uncertainty. The emitted toxic substances such as boron, mercury and arsenic have not been studied properly worldwide. LCA for geothermal power plants needs to be studied considering the manufacturing process of system elements [227]. The environmental impact could be reduced during the operation phase by using technologies such as Abatement System for Mercury and Hydrogen Sulphide (AMIS). To minimize these effects, extensive research is required [228].

The LCA of air cooling multi-generation low-temperature geothermal systems including heating, cooling and electrical power has been studied for environmental impact and energy cost during the life cycle [229]. LCA has been studied for geothermal heating systems based on economic, heat extraction and environmental effect. Two deep-buried heat exchange systems have been studied, coaxial and horizontally-butted boreholes. The obtained results reveal that heat exchanger of type horizontally butted borehole provides better environmental, economic and thermal performances. However, the coaxial heat exchanger type has a lower payback time [230]. The LCA of a binary cycle geothermal power plant for electricity generation has been studied to define the environmental effect and has been compared to other systems. The process of digging, casing, and cementation has been proved to have the most significant environmental effect. The environmental impact could be reduced by extending the lifetime of the plant to 30 years instead of 12 years [231]. A binary geothermal power plant for electricity generation has been studied to evaluate the environmental effects based on LCA. The LCA has been studied based on two scenarios, infiltration of refrigerants and energy required during structure and operation. To ensure the minimum effect, low global warming refrigerants and electricity-based machinery should be used [232].

4.7. LCA for Biomass

LCA for BME has been studied for different applications based on environmental, economic and social impacts as discussed below. LCA has been studied for biomass integrated gasification combined cycles power plants based on global warming potential. Alternative technologies for biomass gasification, CO_2 control and synthesis gas combustion have been investigated. External synthesis gas combustion performs better than internal synthesis gas combustion according to GWP, human toxicity and ozone depletion [233]. LCA for BME has been studied based on greenhouse gas emissions considering different modes of transportation for three power plants which are biomass burning power plant, biomass-coal fired power plants and coal fired power plants [234]. LCA of hydrogen production based on the fluidized bed (FB) gasification, and entrained flow (EF) gasification has been studied based on GHG emission considering thermal efficiency and hydrogen prices. Also, the effect of carbon extraction and liquefaction has been investigated [235].

LCA has been studied from hydrogen production from biomass gasification and conventional natural gas steam methane reforming based on environmental, economic and social impacts [236]. LCA for hydrogen production from biomass and coal has been studied based on GHG emissions and energy consumption considering the production and transportation of raw material, production of synthesis gas, purification of hydrogen and transportation and application of hydrogen [237]. LCA has been studied for the ethanol production process from Miscanthus which is rich in lignocellulosic biomass based on environmental effects [238].

LCA for biomass gasification power plants has been studied based on the emitted GHG and energy costs considering agricultural production integration, industrial process, treatment of wastewater and energy consumption [239]. LCA has been studied for energy generation based on crop residues has been studied considering environmental, economic and social effects [240]. LCA has been studied for energy production based on wastes and biomass residues according to GHG emission and energy production considering different conversion technologies [241]. LCA has been studied for pulverized fuel combustion power plants including the entire power generation process which starts from supplying wood/coal pellets to producing electricity. This study deals with carbon dioxide emissions and the impact of their capture and storage [242].

5. Conclusions and Future Works

Achieving SD requires clean sustainable energy sources; using proper technology, using strategic policy, attractive economic incentives and suitable use of available resources. The electrical power sector is derived towards a green economy to meet load growth, and climate change and provide a secure energy source. But green investment is a long-term investment characterized by a long payback time, a low rate of return investment and it comprises many risks and uncertainties. This paper addresses both technological development and life cycle assessment for wind, solar, biomass and geothermal electrical power plants. It aims to provide affordable clean energy with reduced climate change. RER need more researches to provide efficient, advanced and affordable technologies to harvest more energy, attract more investments and reduce environmental impacts which are negligible compared to fossil fuels.

This paper has provided a review of current and emerging technologies for each type of RER under consideration. In the wind energy sector developments are directed toward designing aspects for different parts of WT, enhancing control techniques, improving operation and maintenance techniques and searching for cost-effective manufacturing and installation processes. In the solar energy sector, silicon-based PV cells dominated other technologies with the highest efficiency followed by thin film and silicon-free technologies, new emerging technologies under research such as bifacial, hollow-conductor and organic solar cells which still have the lowest efficiency. In the biomass energy sector developments are linked to energy conversion systems, producing electricity comes mainly from combustion which is a thermochemical process, biochemical and physicochemical energy conversion systems are used to produce high-energy content substance such as ethanol and biofuel and these substances are used to generate electricity through combustion. GTE is concentrated in developed countries because it is costly, dangerous and required advanced technologies. Their contribution recently is negligible and expected not to exceed 3% by 2050. Most RER are site-specific but if a specific place is suitable for installing all RER types under study, solar thermal power plants would come first followed by solar PV. Wind power plants come next followed by the biomass power plant. Geothermal power plants come last. Most RER systems have different characteristics such as locational, geological environmental and public acceptance.

This paper has also provided a comparison between the environmental effects of RER under consideration and has explained challenges and provided solutions to improve the RER sector and increase green investments. Almost all RER face some common problems such as high investment costs, lack of public awareness, availability of skilled labor, site specific sources and complex expensive advanced technologies. Some other problems related to specific types include wide land use, large wastewater, threats to living beings, bad smells and low efficient energy technologies. Also, there is a great deviation between environmental effects for RER under consideration. The best type with the least environmental risks belongs to solar thermal power plants. The worst type which possesses the highest and most severe environmental effects belongs to geothermal power plants and biomass. Solar PV and wind power plants come in between. Most of the barriers could be avoided as follows:

1. Supporting researchers and developers to provide alternative affordable efficient environmentally friendly technologies.
2. Attracting investors through providing funds and facilities for RER projects.
3. Providing a long-time feed-in tariff with attractive prices.
4. Increasing public awareness of climate change and the importance of RER.
5. Providing technical support for both small- and large-scale RER projects.

6. Policymakers should reduce taxes on construction and maintenance companies.
7. Enhancing electrical networks' ability for RER interconnection.

LCA has been introduced to address RER environmental effects starting from obtaining raw materials passing through the manufacturing process and operating time and ending with end-of-life waste management. It is very important for decision-makers because it provides a good solution to investigate the effectiveness of power plants according to environmental standards. According to the LCA studies for RER under consideration, environmental benefits could be increased through the increasing capacity of each unit, proper selection of place and using recycling materials. There are many factors that affect LCA such as data availability of the system, geographical and geological surrounding, size of the system, and grid interaction with the system. So, many steps would improve the accuracy of LCA studies such as

1. Preparing a database comprising materials, manufacturing, transportation, installation and operation of each power plant for future studies would be beneficial.
2. Integration of optimization techniques and geospatial techniques while modelling power plant and grid interconnection.
3. Considering geographical and geological surroundings while studying LCA.
4. Preparing international standards accurately enough to compare LCA for different plants.
5. Adding investment costs and payback benefits would improve LCA studies.

Researchers compete with each other, so it is recommended for future work to shine light on different topics to enrich this work and treat points of weakness as follows:

1. Focusing on economic benefits for RER to attract stakeholders.
2. Adding optimization and geospatial techniques to LCA studies.
3. Preparing a suitable efficient standard for LCA to evaluate plants efficiently.
4. Providing new studies to address hybridization between different RER plants.
5. Enhancing the flexibility of utility grids for RER interconnection.

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Acronyms

BME	Biomass energy
GDP	Gross domestic product
GTE	Geothermal energy
RE	Renewable energy
RER	Renewable energy resources
SD	Sustainable development
SDG	Sustainable development goal
SE	Solar energy
STS	Solar thermal system
PV	Solar photovoltaic
WE	Wind energy
MPPT	Maximum power point tracking

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