Chapter

Air Pollution and Clean Energy: Latest Trends and Future Perspectives

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Abstract

Energy and the environment are among the top global issues of this era. Environmental degradation specifically due to consumption of fossil fuels in conventional energy generation systems has become a critical challenge for the whole world. With the introduction of advance industrial processes and operations, the air quality deterioration has also become very complex. There is a dire need to replace the conventional energy systems with alternative energy resources for reducing air pollutants. Renewable energy systems generate clean energy with less environmental footprints. This chapter will highlight the latest trends and future strategies in clean and renewable energy supply systems to mitigate air pollution for environmental sustainability.

Keywords: air quality, clean energy, fossil fuels, energy and environment, Air pollution: Sources types and classification

1. Introduction

Air pollution has become a major health hazard to the millions of people around the globe. It has been linked to asthma, heart disease, and other serious health problems. Air pollution triggers asthma, which is a long-term disease of the lungs that affects the airways and makes it hard to breathe. Tiny particles in the air get deep into the lungs and cause inflammation, which can lead to an asthma attack. Cardiovascular diseases such as heart attacks and strokes have also been linked to air pollution. Nitrogen oxides and sulfur dioxide are also causes of oxidative stress, which can lead to heart problems. Various studies have shown that the exposure to air pollution increases the probability of early decay and death among the living organisms. This is especially true for the elderly and people who already have health problems. Adult's lung function is adversely correlated with PM10, nitrogen dioxide, and sulfur dioxide, all of which have been linked to bronchitis symptoms in studies encompassing eight different communities. Research into the effects of air pollution has also revealed a decline in human lifespan [1].

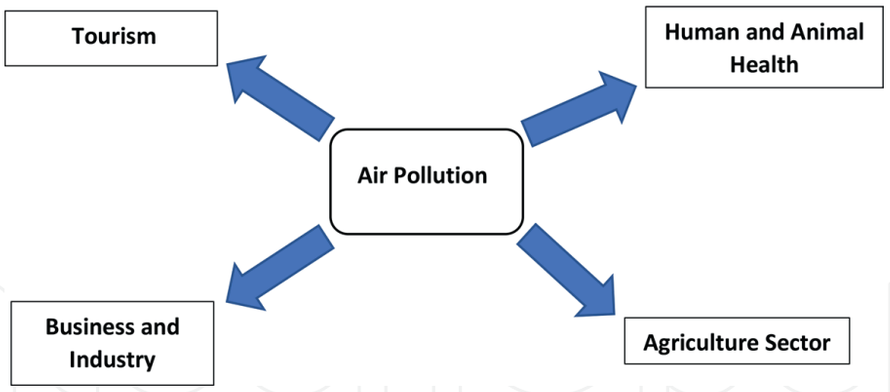

Figure 1.
Effects of air pollution on various sectors.

Air pollution not only harm people's health, but also affects the environment in various ways (**Figure 1**). Here are some primary ways that pollution in the air can affect nature. Air pollutants in form of acid rain have detrimental effects on crops and forests growth [2]. Furthermore, the damage of leaves hinders crop yields [3]. This issue contributes to food insecurity and disturbs plant ecosystems. For instance, acid rain makes lakes and streams more acidic, and it is hard for certain species to survive. Similarly, carbon dioxide, methane, and other greenhouse gases are examples of air pollutants that contribute significantly to global warming and climate change [4]. This results in glaciers melting, rising sea levels, and stronger weather events. The poor air quality causes smog and haze, which makes it difficult for the people to enjoy the outdoor activities [5]. Moreover, air pollution can also have a significant negative effect on various businesses, tourism industry, and ultimately the economy of the region [6].

In order to mitigate air pollution, it is very important to understand the origin, sources, and classification of air pollutants. Moreover, the life cycle of the air pollutant can provide a better insight to manage the potential sources causing air pollution in a system. The major contributor in deterioration of air quality is the energy sector; hence, it is also important to study air pollution in connection with the energy generation systems for sustainability of environment as well as communities. Keeping in view such factors, this chapter summarizes a thorough overview of air pollution, including its causes, types, and classification as well as the use of clean energy resources for minimizing the discharge of pollutants and contaminants in the air. Different factors associated with air pollution such as its effects on health, environment, climate, and the most recent trends in air pollution are also discussed.

1.1 Overview of air pollution

Pollution is addition of any foreign matter, which changes the purity of any system. Hence, air pollution can be defined as "it is the addition of any foreign and undesirable matter generated from physical, chemical, or biological sources which alters the natural quality of ambient air." Having complex mechanisms composed of both primary and secondary pollutants formulations, it is very difficult to exactly determine the air pollution. It might be argued that the use of fossil fuels and primary/finite energy resources is one of the main causes of air pollution. All anthropogenic effluents and emissions into the air are considered as air pollution due to their impact on atmospheric chemistry. Using this definition, the rise in atmospheric levels of greenhouse gases CO_2, CH_4, and N_2O can be considered as air pollution, even

though these levels are not yet known to be harmful to humans or ecosystems. Air pollution can narrowly be defined as harmful chemicals released into the atmosphere by humans. The term "harmful" can refer to a variety of negative outcomes, that is, damage to manmade or naturally occurring inanimate structures, and a decrease in visibility. A chemical may have no immediate negative effects before being released into the environment [7, 8]. Hence, it is important to classify the discrete sources of air pollution for its proper mitigation and minimization.

1.2 Sources of air pollution

Pollutants in the air are divided into groups based on their origin. Based on such classification system, it becomes easy for the environmentalists to make policy decisions for specifying the release and control of air pollutant in the air.

The sources of air pollution are classified into following three major groups (**Table 1**):

1.2.1 Natural sources of air pollution

This category includes the addition of undesirable elements in the ambient air particularly, due to natural incidents occurring in the earth's atmosphere. Such elements that pollute the air include sand or dust particles, forest fires, pollen, volcanic eruptions, SMOG, release of gases from organic matters, etc. These pollutants are liberated as by-products from the cycles or incidents occurring naturally.

Sandstorms are one of the most common sources, which deteriorate the air quality. The immediate effect of sandstorm is to worsen the clarity of air and reducing the visibility and ultimately causing road accidents and difficulties in transportation. Dust particles are more likely to absorb toxic gases, which can cause severe reactions to form secondary pollutants. This also becomes a source of toxic organic compounds

Sources of air pollution	Natural sources	• Sand/dust storms
		• Forest fires
		• Volcanic eruptions
		• Pollen
		• Break down of OM
	Industrial sources	• Emissions from fossil fuels
		• Melting process
		• Processing and treatment plants
		• Crushing and grinding of stones
		• Oil and gas refineries
		• Fertilizers and pesticides
	Municipal sources	• Landfill gas
		• Sewerage
		• Street cleanings/dust removal
		• Household cooking

Table 1.
Sources of air pollution [9–19].

that make aerosols in the urban environment more toxic and biologically reactive. Dust particles act as media to transport bacteria. Studies have shown that microbe-rich dust particles can make allergic inflammation worst [20].

Another source for air pollution is forest fires, which occur as a result of natural accidents like lightning or temperature increase in the certain region that has sufficient biomass to burn up. Open fire at a massive scale in the forest releases a lot of smoke and small particles into the air. Pollutants such as oxides of carbon, that is, carbon dioxide (CO_2) and carbon monoxide (CO), oxides of nitrogen and sulfur in the form of NOx and SOx, volatile organic compounds (VOCs), as well as fine ash and particulate matter are produced from forest fire. These pollutants can lead to health problems like asthma and lung diseases [21].

Volcanic eruptions are one of the most natural and powerful sources of air pollution. Volcano eruption produces aerosol clouds that can travel thousands of miles, blocking the sun and causing health problems, crop damage, and other types of environmental damage. Volcanic eruptions can have far-reaching and terrible effects on the environment in the long run [22].

Similarly, breaking down of organic matter naturally is a major source of air pollution. As organic matter is destructed by the microorganisms in an uncontrolled manner, it gives off gases called volatile organic compounds (VOCs) and other air pollutants. These pollutants can be harmful and can contribute in the formation of smog and ozone, both of which are hazardous to health. Furthermore, such process of organic matter decomposition can also release methane (a strong greenhouse gas), which significantly contributes to climate change and global warming around the world [23].

1.2.2 Industrial or manmade sources of air pollution

Industrial sources of air pollution include all kinds of particulates and gases, which are generated by industrial activities. Stack emissions, that is, release of carbon monoxide, oxides of sulfur dioxide, and oxides of nitrogen due to the burning of fossil fuels, are the most significant elements under this category. Uncontrolled burning of fossil fuels in the energy generation systems at the industrial power units results in complete burning, which liberates toxic pollutants. These pollutants can cause a wide range of health problems, such as cancer and lung diseases. Moreover, such elements are also responsible for the acid rain that damages the local environment and the ecosystem [9].

Metal melting, preparing chemicals, treatment of fluids, and production of cement are all examples of industrial processes that release pollutants into the air [10]. Similarly, farming activities, that is, the use of chemicals in the form of pesticides, fertilizers as well as transportation activities are also the sources of air pollution. Loose and uncontrolled burning of agricultural residues and leftovers has also a major share in air pollution by adding combustion gases directly to the environment leading to the formation of smog and other secondary pollutants [11, 12].

The extraction of minerals and oil and gas refineries are the sources to add sulfur dioxide, VOCs, oxides of nitrogen, and heavy metals into the air [13, 14].

1.2.3 Municipal and domestic sources of air pollution

The municipal and domestic sources of air pollution include methane and other toxic gases produced in the landfills, which contribute to deterioration of air quality in the habitat [15]. Uncontrolled sewage gas is released in the municipal sewerage

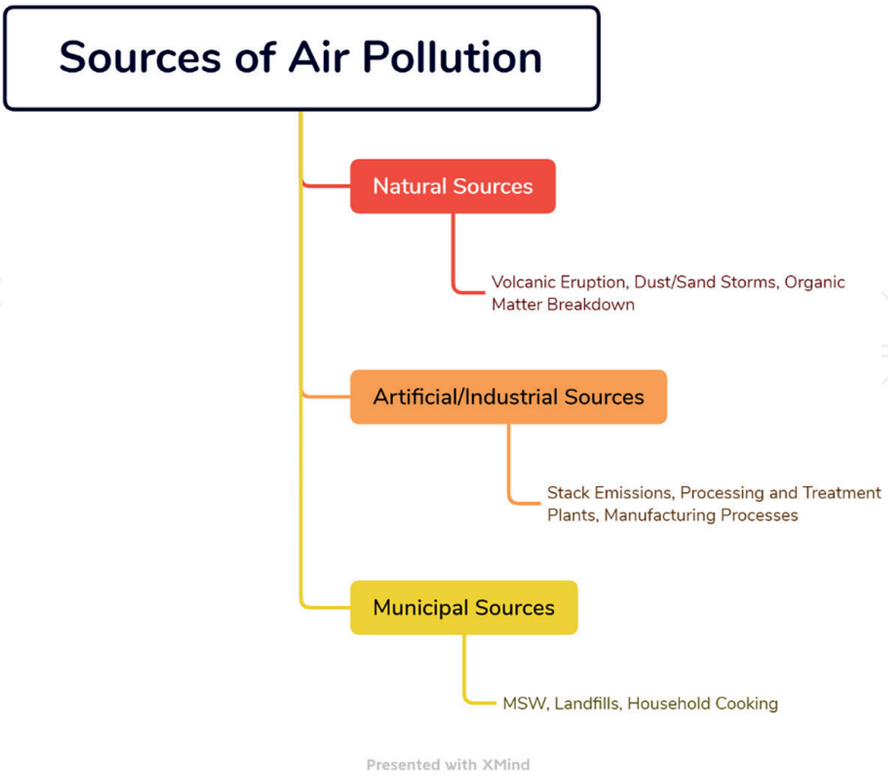

Figure 2.
Sources of air pollution.

systems, which may cause addition of potential pollutants and toxic fumes in the air [16]. Household activities such as cooking are also a source of pollutants such as particulate matter and volatile organic compounds as shown in **Figure 2** [17–19].

The above sources generically include the major contributors in the deterioration of air quality. However, air pollution dates back to the industrial revolution in the nineteenth century. At that time, people burned coal for energy and transportation, which made the air in cities much polluted. The Great Smog of 1952 in London, England, was one of the first documented cases of air pollution. Thousands of people were affected, which led to the formulation of the Clean Air Act in 1956 [24]. In the 1960s and 1970s, after being more aware about the possible effects of poor air quality and contaminants on health and ecosystem, further strict rules were also structured such as the Clean Air Act Amendment, which was passed in 1963. The formulation of Environmental Protection Agency (EPA) in the United States in 1970 also played an important role to control air pollution (Environmental Protection Agency, 2023). In the last few decades, air pollution has become a global issue. The rapid growth of industry and transportation has affected the air quality badly.

2. Potential air pollutants

As described earlier, the air pollutants are generated from the various sources and undergo a series of complex mechanisms that ultimately affect the natural environment. However, the major identified pollutants generated from the above sources are discussed as below:

2.1 Particulate matter (PM)

Particulate matter (PM) is one of the basic air pollutants, which is formed when different pollutants react chemically. The particulate matter has different particle sizes ranging from 10 μm to very fine particles having particle size of 0.5 μm or less. Such particles are made up of tiny drops of liquid or solid that can be breathed in by human and cause serious health issues such as lung infections and contamination of even bloodstream [25–28]. Both short-term and long-term effects are caused by PMs. Several epidemiological studies have been conducted to investigate such effects. Such effects include asthma, pneumonia, respiratory, and heart diseases [29, 30].

2.2 Ozone (O_3)

Ozone or ground-level ozone is formed due to reaction of flue gases (particularly VOCs and other hydrocarbon) released during the incomplete combustion of fossil fuels. This is a highly reactive gas that can cause coughing, wheezing as well as difficulty on enough air. This is considered as 52% more stronger oxidant as compared to chlorine [31–35].

2.3 Oxides of nitrogen (NOx) and sulfur (sox)

Oxides of nitrogen and sulfur are formed during uncontrolled and incomplete combustion of fossil fuels. Oxides of nitrogen include NO (nitrogen monoxide), NO_2 (nitrogen dioxide), and N_2O (di-nitrogen oxide). These gases through different chemical reactions are responsible for smog formation as well as acid rain. Similarly, oxides of sulfur are formed due to the impurities found in fuel being burnt in the firing system. It is very important to prevent these gases before they enter in the environment [36–38].

3. Air pollution and climate change

Air pollution is directly linked to the climate change and global warming. Some of the effects include rising sea levels, heatwaves that happen more often, droughts, and extreme weather events such as hurricanes, floods, and wildfires. The loss of biodiversity and changes in agricultural production are also the negative outcomes of the climate change. Almost all kinds of air pollutants are directly or indirectly involved in global warming resulting in uncertain climatic conditions. For instance, emissions from vehicles, industries, and domestic activities including combustion by-products comprising of carbon mono oxide, carbon dioxide, nitrogen oxides as well as char particles (in the form of particulate matter). Such particulate matters absorb or scatter radiation with greater capacity as compared to air and hence impart a direct impact on climate change, which may harm human, animal as well as plant health. Similarly, methane is another pollutant that contributes to climate change as its global warming potential is much higher than carbon dioxide. Possible options to cope with climatic issues and ambient air quality include an improvement in the environmentally efficient energy generation systems, less thermal losses, and use of clean energy resources to reduce emission levels around the globe [39–42]. Controlling air pollutant can have a direct and positive impact on the climate change and improves quality of

environment. For this, it is very important to revise the policies for energy generation, which can minimize the consumption of fossil fuels.

4. Clean energy: introduction and overview

Energy is one of the main sectors, which contributes a major share in the environmental degradation, particularly in air phase of the environment. Conventionally, fossil fuels are used for meeting the environment requirements of industrial, commercial, transportation, domestic as well as agricultural operations and activities. Fossil fuels are excavated from the earth and after going through a series of refining processes are consumed in the energy generation systems. Burning of such fuels in the firing system acts as a baseline in the formation of primary air pollutants. Hence, technical aspects of the fossil fuel burning in the firing system are extremely important to minimize the environmental impacts. Such measures include use of refined fuels, design of combustion systems, firing methods, air to fuel ratios, filtration and scrubbing systems for smoke in the stacks as well as quality of fuel. Despite several measures, there is still likely chance of release of harmful gases from the burning of fossil fuels, which may seriously affect the air environment. Moreover, rapid depletion of fossil fuels results in high energy prices around the world. In this case, this causes both high economic costs and environmental costs. It is dire need of the time to introduce alternative energy generation ways, which can replace the need of fossil fuels (**Figure 3**) [43].

The economic, social as well as environmental constraints caused by the use of fossil fuels in energy generations system have pushed the community to use the renewable energy resources for meeting the energy requirements. Having no emissions and effluents, renewable energy resources are considered clean energy resources. The renewable energy resources, that is, clean energy resources are categorized in different groups such as Solar Energy (SE), Wind Energy (WE), Geothermal Energy (GTE), Bioenergy (BE), and Hydro Energy (HE) as shown in **Figure 4**.

Having a natural cycle in the earth's atmosphere, all kinds of clean energy resources (**Figure 4**) have zero or minimal impacts on the environment and hence

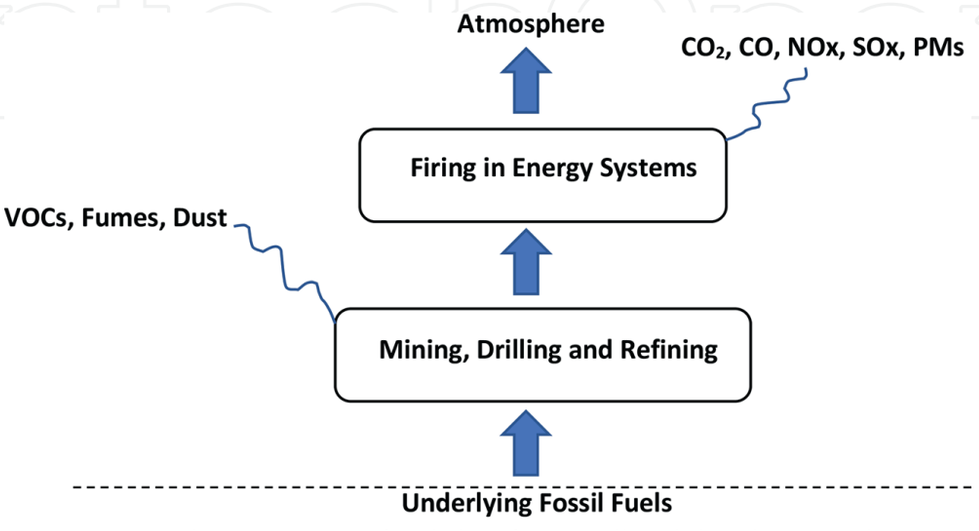

Figure 3.
Sources of emissions from fossil fuels into the atmosphere.

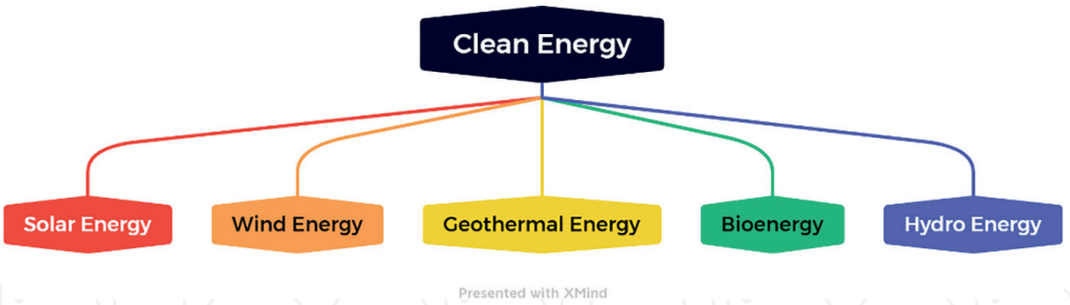

Figure 4.
Types of clean energy.

contribute to mitigate the air pollution as well as greenhouse gases. This creates more balance in the earth's environment contrary to the fossil fuels that disturb the natural balance and cause natural hazards. Further, there are several benefits to invest in such alternative energy generation techniques including lowering the energy costs, fulfillment of energy gaps due to rapid population growth, minimal environmental impacts, improved public health sustainable, creation of employment and business opportunities, and hence, development of societies and communities [44]. The modern technological advancements and innovations have made such resources more efficient and cost-effective and easier to use in place of conventional fuels and primary energy systems [45].

Different incentives and subsidies are being provided around the world for the promotion and adoption of clean energy resources in domestic, commercial as well as industrial applications around the world. However, there is a need of more friendly policies for the encouragement of such technologies so that social implications can be avoided for the successful adoption of clean energy [46].

It is important to study and understand the basis and technical aspects of clean energy resources for successful adoption. The major clean energy resources and their systematic flow of energy generation in line with its connection to mitigate air pollution are discussed as below.

4.1 Solar energy as clean energy resource

Sun is the most prominent and basic source of energy for the Earth. This is also considered to be the first-stage energy source for all kinds of clean energy resources as the energy flows in the form of solar radiation from the sun's surface toward earth's environment and is absorbed or captured by various ways. This is considered as renewable resource as a continuous flux of solar energy (solar rays) rays is received by the earth. A portion of these rays is absorbed by the clouds, dust particles, or moisture/gas molecules, another portion is reflected back to the environment, and a significant part is absorbed by the earth surface [47, 48]. If a device is placed in the path of solar rays, the energy possessed in the solar radiation can be captured to process further to the desired form of energy (**Figure 5**).

The energy flux coming from the solar source can be captured for two purposes, that is, 1—Solar Photovoltaic (PV) generation and 2—Solar Thermal Energy (**Figure 5**). The former is based on a simple P-N junction diode cell to capture photons present in the sunlight to produce a flow of electrons, which is used as an electrical energy input for various applications. Another application of solar energy is to capture and concentrate the solar radiation to produce a high-density flux of radiation resulting

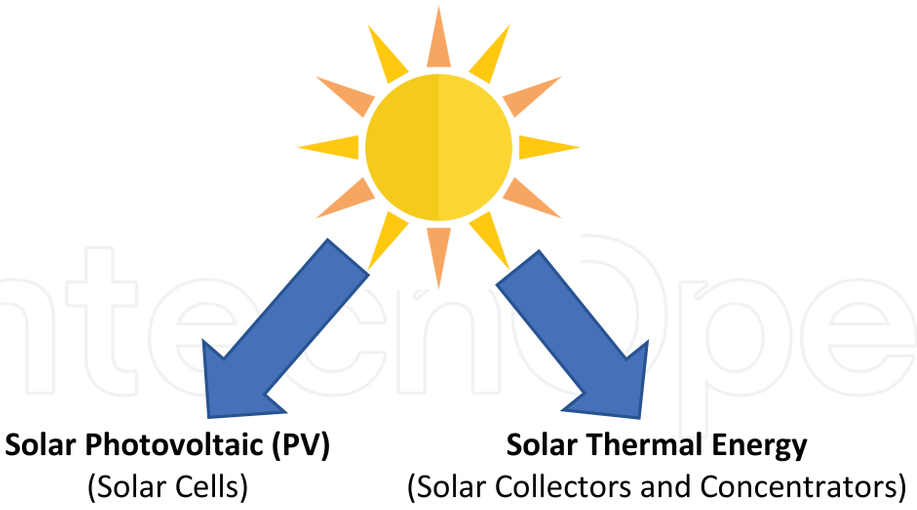

Figure 5.
Outputs of solar energy [49].

in a significant temperature output, which can be used in various thermal energy applications such as water heating, drying of agricultural products, cooking, and processing of chemicals and solutions. The device used for such purpose is termed as Solar Collector and Contractors. In solar collectors, the solar radiation is captured and absorbed by the black body present in the solar collector, while in case of solar concentrators the solar radiation is contracted with the help of mirrors and focused lenses to produce a high temperature. By using both techniques, the energy requirement in both forms, that is, electricity and thermal energy can be fulfilled, which is conventionally provided by the burning of fossil fuels and other primary energy resources. A multiscale installation of such system can provide sufficient energy for town. There are certain technical challenges such as solar fluctuations, day of the time, and climate and weather conditions, which hinder the proper availability of solar rays. However, these aspects can be managed by using storage systems as well as installation of auxiliary energy system, which can be used during the time of no or less solar energy. The use of solar energy is helpful to reduce dependence on fossil fuels to meet both electricity and thermal energy for industrial and domestic applications [49].

Adoption of solar energy also provides a promising solution for the transport sector, which is one of the significant contributors for air pollution and environmental degradation. Electric vehicles (EVs) powered with solar energy are one of the alternative solutions to the conventional transportation vehicles being run by firing the fossil fuels like gasoline, diesel. The use of EVs does not release any harmful pollutants into the air. This is particularly important for the big and populated cities where transportation is major cause of respiratory and heart diseases. Availability of solar PV powered recharging stations can further help to further disseminate this environmentally friendly technology [50].

Solar energy could be combined with other clean energy sources, like wind, bioenergy, and hydroelectric power, to make a more reliable and efficient energy system. There are still certain challenges and barriers that make it hard for solar energy to be used at a large scale. However, this also highlights a lot of opportunities and future directions for introduction of modern tools and systems, which can eliminate the technical problems and promote further sustainability. In this regard, life cycle assessment, energy balances as well as energy routing of solar PV cells and collectors are also needed for the technological advancement of this environmental technology.

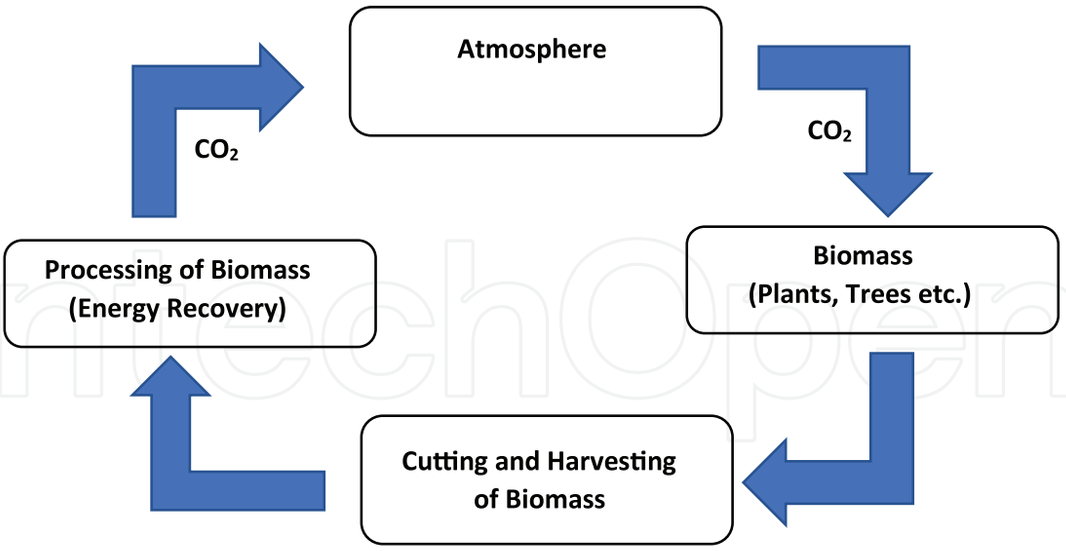

Figure 6.
Closed biomass cycle (zero net emissions) [51].

4.2 Bioenergy as clean energy resource

Bioenergy is another type of clean energy resources, which is also considered to be an alternative to many fossil fuels and conventional energy resources. Bioenergy is based on the energy extraction from biomass materials, i.e., organic matter generated from living bodies such as plants and animals. Use of biomass materials for the production of energy is considered as net zero emission technique on the basis of natural cycle of plants and organic matter. Under this concept, the same amount of carbon dioxide as well as temperature is returned to the natural environment, which was taken during the growth of biomass matter such as plants (**Figure 6**). This makes it clean source of energy as compared to the fossil fuels that are taken up from the earth or mines and after burning an additional volume of greenhouses gases is added in the atmosphere [51–53].

Biomass materials are generated as by-products during the decay of forest trees, crop production as well as raring of livestock animals. Such materials consist of significant energy contents in the form of calorific value or heating value (MJ/k), which can be recovered to meet the energy requirements. This recovery can be executed in various ways (**Table 2**).

In simple and basic energy recovery techniques, the raw biomass material is cut, chopped, and physically processed to produce a more refined form of organic matter, which can be used in other processing techniques with higher efficiency. For example, biomass materials are crushed and ground into fine particles, which are then densified with high pressure and are allowed to pass through the dyes of known size resulting in small fuel structures in the form of pellets or briquettes termed as Refused Derived Fuel. In case of oily biomass and seeds, the oil extraction technique is used. Similarly, in Thermo-Chemical Processing, biomass materials are treated and destructed under controlled temperature conditions to produce high temperature, pyrolysis oil, or more refined gaseous fuels, which can be used in place of conventional fuels. In Biological Processing, the breakdown of biomass materials occurs biologically, that is, by the microorganisms to produce secondary fuels like biogas, biodiesel (**Table 2**). Being the part of natural cycle, biomass can be used to replace

Sr. No.	Processing	Technique used	Output
1	Physical processing	• Cutting and chopping • Densification • Pelleting • Oil extraction	• Refused derived fuel (RDF) • Biofuel pellets • Oil
2	Thermo-chemical processing	• Combustion/incineration • Pyrolysis/electrolysis • Gasification • Transesterification	• Thermal energy • Pyrolysis oil • Gaseous fuel (Syngas)
3	Bio-chemical processing	• Anaerobic digestion • Fermentation • Landfilling and bioreactors	• Gaseous fuel (Biogas) • Biodiesel • Biofuel

Table 2.
Energy recovery of biomass [51–53].

the fossil fuel to minimize environmental impacts and air pollution, in particular. However, attention must be given to use the suitable energy conversion technique for better outcomes [52, 53].

4.3 Wind energy as clean energy resource

A very high energy potential is possessed by winds blowing at high velocities. This is because of the natural convective loops caused by the temperature difference in different regions. Due to this factor, this is considered as a by-product of solar energy. The high speed and impact of wind is converted into mechanical energy and then to electricity by using wind turbines. Various designs of wind turbines and mills are used for this purpose, depending on the available potential of winds in a particular region. Primarily, wind turbines are classified into 1—Horizontal Axis Wind Turbines and 2—Vertical Axis Wind Turbines. In the first category, the wind turbine rotates in the horizontal plane and it is governed by lift force of the winds. On the other hand, Vertical Axis Wind Turbines rotate in the vertical plane by drag force of winds. There are certain drawbacks and benefits for both the categories. However, it is important to check the feasibility of both designs for the desired location. The speed of the wind can change a lot over time, which can make it hard to rely on wind energy alone to meet energy needs. Therefore, a stable and reliable energy supply requires energy storage systems or backup power sources [54, 55]. The feasibility of optimum design of wind turbine can be achieved by using different simulation tools such as CFD, which can provide a true insight of thrust and impact of winds on solid body of the turbines. Based on such simulation results, the turbine height can also be adjusted for maximum output. Many countries have set high goals for generating renewable energy. Wind energy is expected to continue to play a big role in reducing air pollution and slowing climate change in the future. Modern energy generation systems particularly at seashore are equipped with such technologies for harvesting of maximum energy from winds. As per an estimate, this technology is expected to meet around 18% of the world's electricity demand by 2025 [56, 57].

4.4 Geothermal energy as clean energy resource

Geothermal energy refers to the energy extracted from earth core. The major benefit of this technique is the continuous and persistent potential of energy as compared to the other renewable energy resources. The high temperature in the earth core is extracted with the help of drilled pipelines filled with thermal fluid, the most commonly water. Sometimes, earth is taken as heat sink to increase or decrease ambient temperature. This is based on the concept that earth's temperature beneath the earth's surface remains constant throughout the year. Depending upon the local climatic condition, if a fluid is allowed to be injected in the earth surface with the help of heat conductor material (i.e., copper pipe), this will help to maintain the temperature as per earth's temperature. However, optimum depth, length, and orientation of pipe and the ambient weather conditions are the important factors influencing this technique. Buildings equipped with such technique will reduce the energy consumption for both cold and hot climatic conditions [58–61].

4.5 Hydro energy as clean energy resource

Hydro energy also sometimes termed as hydropower refers to the energy extraction from the kinetic energy possessed in the water. This is most suitable for hilly areas or natural water retaining locations where water has sufficient potential energy. In other words, a large volume of water is captured at a high altitude from where it is allowed to pass through a narrow path resulting in a very high speed of water stream. The hydro turbine is placed in this path, which converts the kinetic energy of water to electrical energy [62]. It is a source of energy that has been used for centuries, but in recent decades, it has been increasingly popular to reduce the emissions of greenhouse gases and ultimately mitigate air pollution. According to the International Hydropower Association, adoption of this technology, that is, hydropower contributes to prevent around 4 billion tons of CO_2 emissions every year across the globe [63, 64]. This is correlated with removing more than 1 billion cars from the road. There is a wide range of sizes and configurations available for hydropower plants, and they can be constructed on rivers, streams, or other bodies of water. Small-scale hydropower plants are only capable of producing a few kilowatts of electricity, whereas large-scale hydropower plants can produce thousands of megawatts [65].

5. Conclusions

Energy sector needs particular attention to mitigate environmental pollution, particularly for the case of air segment. Environmental degradation, because of consumption of fossil fuels and other primary energy resources in energy sector, has become critical challenge for the today's world. The cost of affordable energy is also growing drastically, which ultimately affects the overall per capita income. The air quality deterioration has also become very complex due to introduction of various new industrial processes and operations. Use of renewable and clean energy resources provides sustainable solution to both problems, i.e., fulfilling the energy requirements as well as mitigation of environmental pollution. Having natural cycle and occurring in the form of natural flux, such techniques have either zero or minimal impacts on the environment.

The future trends for the mitigation of air pollution in line with energy needs are summarized as below:

- Promotion of friendly policies and subsidies for the successful adoption of clean energy resources.
- Use of electric cars and vehicles powered by clean energy resources in the transport sector.
- Use of catalytic converters and filtration mechanism in the existing vehicles to avoid toxic emissions in the air.
- Utilization of modern IOT and AI tools for monitoring and predicting air quality so that real-time data can be collected, which could help researchers and policy-makers to make appropriate solutions for sustainable environment.
- Implementation of environmental laws and effluent standards particularly in energy sector.
- Awareness among the community about short-term as well as long-term effects of air pollutants to make and adopt community scale preventive measures.
- Precision farming and proper management of agricultural residues to avoid open burning of residues, wastes, and organic matters.

Conflict of interest

There is no conflict of interest.

Notes/thanks/other declarations

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