# 3

# Recent Advances in Alternative Sources of Energy

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## 3.1 Introduction

Energy has occupied a predominant space in the existence and development of mankind. However, humans seek more and more sources of energy from the time immemorial. The demand of energy has drastically increased with the growth in population. To meet the energy requirements, there is a constant search for the alternate sources of energy. In the quest of meeting energy requirements, one should also be considerate towards its effects on the environment. At present, most of the energy requirements are fulfilled by non-renewable resources. However, these resources suffer from several disadvantages like limited availability, long time duration for their formation and non-sustainable, greenhouse gas emissions. The emission of carbon dioxide, methane and other harmful gases that are the main cause of global warming may result change in the weather patterns which in turns affect the ecosystems (Wang et al. 2020a). Apart from the air pollution, excessive usage of fossil fuels results in water pollution, land pollution, climate change etc. All these pollutants severely affect the human health and environment. Burning of coal emits mercury, which on inhalation by the human beings and other animals may lead to neurological disorders (Munawer 2018). Many pollutants emitted due to burning of fossil fuels may enter the water cycle and cause acidic rain. This acidic rain when mixes with the water bodies can severely harm the aquatic animals and plants. Acidic rain may also cause corrosion to machineries and monuments (Munawer 2018).

Thus, there is an urgent need of technology which can replace these resources with sustainable energy sources. Renewable energy resources are the potential candidates that could produce energy much greater than the actual energy requirements. These are the sources which can be continuously replenished by nature such as sunlight, wind, water etc. Our ancestors had realized the importance of these resources very long back and described them as powerful energy sources in Vedas. In the twenty-first century, huge investment and

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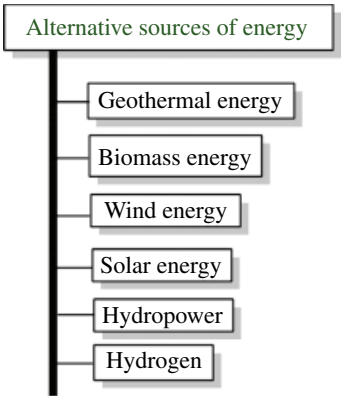
growth have been proposed in alternative energy sources all over the world (IEA 2019). IEA also expects the growth of renewable energy share to reach 30% by 2024. Recent research is based on either to make use of renewable resources or to develop new technologies which could replace non-renewable sources and meet the future energy demands (Chel and Kaushik 2018; Gielen et al. 2019; Peter and Mbohwa 2019). Recently, the generation of energy from waste products has drawn the attention of scientists due to their reduced costs, increased profits and reduced environmental impacts (Shariar and Bustam 2012). In this chapter, recent developments in the alternate energy sources and their contribution in sustainable development have been discussed.

## 3.2 Different Innovations Employed in Major Types of Alternative Sources of Energy

Renewable energy sources are the clean and sustainable energy supplies. Various types of renewable energy resources have been used to generate energy (Scheme 3.1). The driving force behind the development of renewable resources and innovative technologies is energy security. The security of energy is the prime requirement of a country's development policies. Apart from ensuring energy security, these sources have resulted in improving the economy of the countries due to more industrial set-ups and air quality due to less pollution. Importing fuels can affect country's economy. Instead of importing non-renewable fuels, if a country set up its own industries making use of renewable resources, it will open the scope of investment in other sectors. In this manner, country's economic growth will be improved. As these resources do not cause pollution and contribute towards sustainable development, these are also called clean energy sources. Recently, various alternative sources of energy utilize innovative technique for their improvement in working and energy generation (Table 3.1). Various types of renewable energy sources are generating energy by using different techniques which are discussed below.




**Scheme 3.1** Different alternative sources of energy.

### 3.2.1 Solar Energy (Semiconductor Technology to Harness Solar Power)

The energy from sun is one of the predominant and sustainable renewable energy resources for generating energy. It is obtained from the sun and utilized for heating, lighting and generating electricity. Passive solar and active solar are the two types of solar energy. Passive solar energy utilizes the direct and indirect thermal energies from the sun to heat water, whereas active solar energy can utilize the electromagnetic radiation from the sun for the generation of electrical energy (Alrikabi 2014). However, the topographical region and seasons are the major factors which affect the solar energy harnessing. In addition, it involves

**Table 3.1** Various technologies employed in the development of renewable resources and their applications.

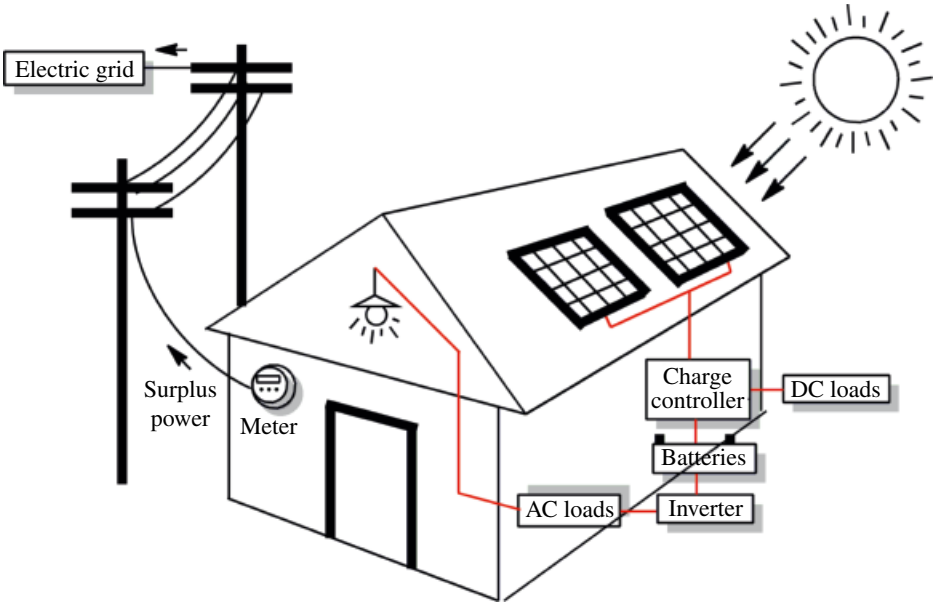
| Renewable energy sources | Technologies involved | Applications | Challenges |
|---|---|---|---|
| Solar | Semiconductor technology for solar panels, photovoltaic cells, solar cooker, dye-sensitized solar cell, quantum dots | Electricity generation, heating, cooking, satellite, remote industries | Costly due to semiconductor technology involved, weather dependent |
| Wind | Conventional wind mills, onshore and offshore wind turbines | Power generation | Depends on direction and speed of wind, maintenance cost of wind tower and turbine blades |
| Geothermal | Geothermal heat pumps | heating, bathing, cooking, power generation | Location specific, high cost involved in geothermal heating/ cooling systems |
| Hydropower | Building dams, control techniques for its operation | Power generation | Cost involved in building dams, environmental concerns, relocating residents |
| Biomass | Combustion, gasification, hydrolysis and fermentation, pyrolysis, anaerobic digestion | Electricity generation, heating, fuel for cooking and transport | Undesirable high moisture content, low density causes handling of large amount of biomass |
| Hydrogen | Nanomaterials for storage, hybrid fuel cell turbines, e-fuel | Fuel cell electric vehicle, electricity generation | Difficult to store and transport |

high cost for implanting solar panels as compared to conventional resources based on plants to generate electricity.

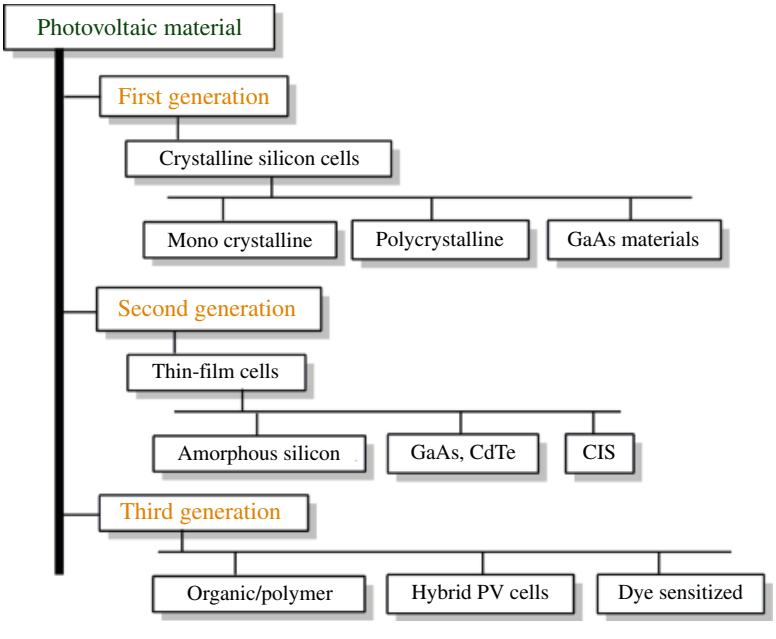
Solar energy technologies (i.e. photovoltaics [PV], solar thermal) offer a clean, renewable and domestic energy source for sustainable energy future in comparison to the traditional energy sources. PV can be used to generate electricity through semiconductor technology in the form of solar panels (Scheme 3.2). Solar PV power can be used for a number of applications such as in satellites, remote industries, solar home systems etc.

The photons received from the sun excite electrons and produce electricity. PV cell is an example of sustainable energy harvester which can transform solar energy into electricity. It makes use of semiconductor technology. There are three different generations of PV cell, namely first generation, second generation and third generation (Scheme 3.3).

Crystalline silicon cells are the first generation and the most common types of PV cells due to the matured technology and high efficiency. They can absorb photons with energies lying in the visible light as well as some photons from the infrared range of the spectrum. However, due to the high cost of monocrystalline cells, different alternative materials such as polycrystalline, GaAs materials are used to manufacture solar cells (Deb 1998). Recently,




**Scheme 3.2** Schematic representation of photovoltaic cell.




**Scheme 3.3** Schematic representation of different types of photovoltaic cells.

low-cost, highly flexible and lightweight thin-film-based solar panels have been utilized in the power generation; it is also known as second-generation cell (McCann et al. 2001).

Thin-film solar panels with enhanced efficiency have been developed using various materials such as amorphous silicon, cadmium tellurides, copper indium gallium diselenide etc. (El Chaar and El Zein 2011). Third-generation solar cells constitute a variety of PV cells such as the concentrated solar PV (CPV) system, hybrid cells, organic PV cells, dye-sensitized solar cells (DSSCs) etc. (Scheme 3.3). CPV technique has been used to generate electricity by making use of mirrors to focus sunlight on the receiver using concentrating solar power technique (Looser et al. 2014). In comparison to the other solar cells, these cells involve the utilization of lesser materials and offer viable and cost-effective technology with higher efficiency. Organic solar cells are another PV cell which is in demand nowadays as an alternative for solar cells due to their mechanical flexibility, low cost, lightweight etc. However, these cells possess lower efficiency in contrast to other types of solar cells (Dou et al. 2012). Recently, the high-performance solar cells have been developed using different donor, acceptor and/or bulk hetero junction (BHJ) structures (Bagienski and Gupta 2011; Parvathy Devi et al. 2011). Recently, the hybrid cells have been fabricated by using a combination of both inorganic (e.g. Si, nanoparticles) and organic (e.g. conjugated polymers or small organic molecules) materials (Moule et al. 2012). Also, DSSCs have drawn the attention of researchers due to their less expensive and simpler methods of manufacturing as compared to other methods (Figure 3.1) (Shalini et al. 2015). This method makes use of dyes to convert solar energy to electricity. The dyes used may consist of organic, metal–organic and inorganic molecules or may be extracted naturally from different parts of plants (Xing et al. 2016; Narayan 2012; Hao et al. 2006).

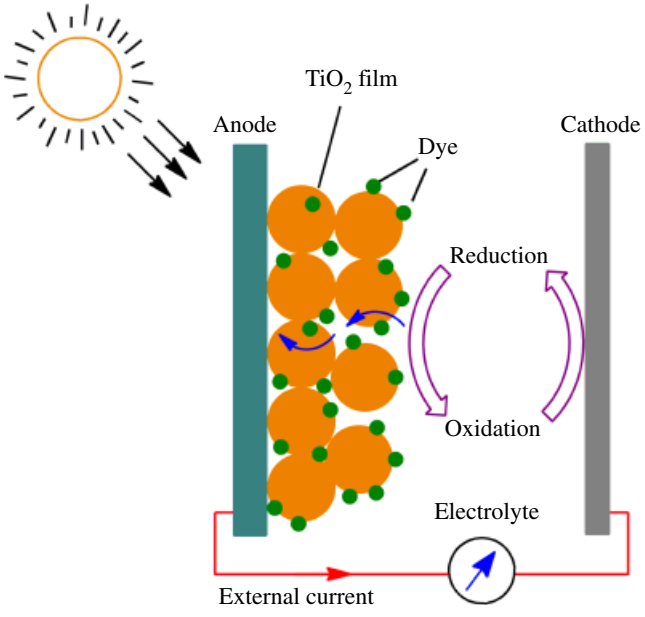



**Figure 3.1** Schematic representation of dye-sensitized solar cells. *Source:* Modified from Shalini et al. (2015).

Nowadays, researchers are attracted towards development of smart windows which act as energy regulators and energy harvesters (Wang et al. 2016). It has been reported that using a coating of semi-transparent perovskite solar cell and multilayer nanophotonic on smart window device can be used as an energy harvester (Wang et al. 2020b). Various PV technologies have been employed in different areas with a cost-effective and enhanced technology. Similarly, Quantum dots (QD)-based LEDs have been employed in high-power devices with enhanced efficiency. They posses several advantages such as colour purity, broad wavelength range, stability and low production cost. Recently, QDs have been employed in solar PVs for the development of QD-based solar cells (Ambika and Singh 2018). Solar energy can also be used for heating systems with different types of solar collectors. Flate plate solar collector (FPSC), integrated collector storage systems and evacuated tube collectors are some of the examples of solar collectors (Kabeel et al. 2016; Mallah et al. 2019). FPSC transfers solar energy radiations to circulating fluid in collector pipe to increase its temperature. Nowadays, researchers are using nanofluids instead of regular fluid due to its more effective thermal properties of heat absorption and transfer (Zayed et al. 2019). Solar cookers with compound parabolic concentrators have been developed which is very beneficial in rural communities, where wood is still used as a fuel and its burning causes respiratory problems (Lopez Sosa et al. 2014). It also provides the most important source of electricity for carrying out space programmes. According to IEA report 2019, there is a prediction that contribution of solar energy will be 60% of the renewable growth and expansion due to solar PV in renewable power capacity by 50% till 2024 (IEA 2019). Though it is advantageous due to low maintenance cost and forever availability, this energy can be utilized in favourable seasons and at suitable geographical regions. The main concern to utilize this energy source is its dependence on weather conditions, resulting in reduced solar power generation.

### 3.2.2 Hydropower

This methodology involves the generation of electrical energy by utilizing the renewable source of water (Kaunda et al. 2012). Generally, hydroelectric power is generated by constructing the dams near moving water bodies. The basic principle involves the utilization of the kinetic energy of moving water which operates the mechanical dynamos to generate electric power. However, this technique suffers from some disadvantages like ecological imbalance due to geological changes in the area surrounding the dams.

Various innovative techniques have been employed in hydropower for the reduction of dam construction and power generation costs (Kougiasa et al. 2019). There are some control techniques such as passive control techniques, active control techniques and magnetorheological control techniques for the operation of hydropower plants effectively. Recently, fish-friendly turbine such as Alden turbine and Minimum gap runner turbine was designed for the smooth passage of fishes, through the turbine with minimum pressure within water passage. Alden turbine operates at a slower rotational speed with three blades to decrease fish death due to blade strike. In case of minimum gap runner turbine, the gaps between the adjustable runner blade and the hub have been reduced as compared to conventional turbines (Hogan et al. 2014).

### 3.2.3 Wind Energy

A wind mill is a machine which utilizes the kinetic energy of wind for the production of electricity using a generator. Generally, wind turbine can work in the horizontal axis and vertical axis. Wind turbines location has huge impact on the performance of the machine. Wind energy is eco-friendly, non-polluting and produces no hazardous emissions. Also, while utilization of wind, the land can be used for farming purpose and to collect solar energy (Alrikabi 2014; Zhang et al. 2020). Recently, it is reported that the use of wind energy can save twice of the fossil fuel which in turn has a positive impact on socio economy and environment in Europe (Izquierdo and Rio 2020). As the wind farms are set up on agricultural or fallow lands, they fetch extra income to the farmers or other persons involved in these activities, hence improving the economic condition. The challenge to harness wind energy is the cost involved in repairing wind towers and turbine blades which may get damaged due to high winds.

Various innovative techniques have been used in the development of generation of electricity using wind energy. The power generation using wind energy is reported to be significant in European countries (Monforti et al. 2016; Zhang et al. 2020). Recently, an advanced concept airborne wind energy (AWE) which can transform wind energy into electricity by the use of aerodynamic or aerostatic lift devices has been developed (Ahrens et al. 2013). AWE technology can operate at higher altitude and utilizes less material, lower cost of manufacturing in comparison to conventional turbines. Similarly, offshore floating wind turbine has been developed to generate electricity in water depths (Jonkman and Matha 2011). These types of turbines can significantly increase the sea area available for offshore wind farms. Floating hybrid energy platforms are another innovative technique used to generate electricity. Hybrid energy platforms are a technique which utilizes the combination of at least two different energy types or technology types for power generation (Roy et al. 2018). For example, blackbird system utilizes the combination of wind with wave energy (Golightly 2017). SCDnezzy is another example of hybrid system which exploits both conventional and airborne wind energy converter on the same platform (De Vries 2018). Japan is also in the process of replacing nuclear reactors with offshore wind turbines after Fukushima nuclear disaster. The hybrid power system comprising distributed wind energy source and solar energy results in enhanced power generation (Allan et al. 2015). The modifications in other parts of wind mill have also been developed for the enhanced functioning. For example, the development of smart rotors involves the adjustment of the blade size according to harsh environment wind conditions, etc. (De Vries 1979; Barlas and van Kuik 2010). Nowadays, diffuser-augmented wind turbines have been developed with a funnel-shaped wind that can collect and concentrate the entering wind. Further, the performance of the diffuser can be enhanced by modifying the diffuser by the addition of a broad ring around the exit point and an inlet shroud at the entrance (Ohya et al. 2017). Recently, large single rotor has been replaced with a multiple-rotor system (MRS) to enhance the efficiency of a wind turbine.

### 3.2.4 Geothermal Energy

Geothermal energy is derived from the earth's sub-surface to produce steam, which then powers turbines to produce electricity (Alrikabi 2014). It has historical significance and is used for heating, bathing and cooking purposes. The advantage of using this source of

energy over solar and wind energy is its availability all the time, i.e. it could be utilized at any day of the year.

Geothermal energy is the form of energy which can be harnessed by using geothermal heat pumps (GHPs) for heating and cooling purposes. GHP transfers the heat of a building into the ground during summer and carries heat from the ground into the building during winters (Pareek et al. 2020). In United States, geothermal energy has brought economic growth in both rural and urban areas. Recently, a model for the estimation of economic potentials of geothermal energy in European countries has been developed (Limberger et al. 2014). It is estimated that the contribution of geothermal plants towards electricity generation in European countries will be enhanced significantly by 2050 (Longa et al. 2020; Olabi et al. 2020). These are expected to be useful energy resources in future due to their presence in abundance. Recently, a dual-source heat pump prototype (DSHP) as air-conditioning system has been developed with overall energy saving (Bottarelli 2019). Integrating geothermal energy with other renewable sources results in increased output efficiency (McTigue et al. 2020).

### 3.2.5 Biomass Energy

Biomass is the organic matter obtained from animal wastes and plants residues. Biomass energy is generated when organic matter is converted to energy. It comprises solid biomass, liquid biofuels, biogas and other wastes. Solid biomass includes organic matter such as wood, other agricultural products and animal dung. Liquid biofuels such as biodiesel, mainly used in transport sector, are produced using plant and animal wastes. Biogas is released in the form of methane and carbon dioxide when organic matter undergoes anaerobic digestion. It is mainly used for heating and power generation applications (Caposciutti et al. 2020).

The non-renewable fossil fuels like petroleum, diesel, natural gas etc. are depleting rapidly with the rise of industrialization. Innovations are required to generate energy from wastes, called bioenergy, for a sustainable approach. In this manner, bioenergy generation solves the current problem of waste disposal and hence resolving the issues related to climatic changes (Dhanya et al. 2020). The energy derived from biomass is used for heating, electricity and fuels purposes. Biomass is the organic matter obtained from animal wastes and plants residues. Recently, a variety of biomass conversion processes have been developed and exploited such as thermochemical processes, bio-refinery, biogas etc. Biomass is converted into gas such as methane by gasification process, which in turn is used to generate electricity. Biofuels in liquid form such as ethanol can also be derived from biomass for power generation purposes. Biomass has been utilized as the potential source of alternative energy in Bangladesh for cooking purposes (Uddina et al. 2019). Recently, researchers have developed sustainable and innovative methods for the production of energy. For example, various food and plant wastes have been utilized for the production of biomethane and bioethanol which may further be used as energy harvesters for various purposes such as transportation, power plants and composting (Shuit et al. 2009; Chiew and Shimada 2013; Ma et al. 2017; Gutierrez et al. 2018). Pomelo peels when treated with phosphoric acid and KOH to prepare carbonaceous structures result in cost-effective, eco-friendly, high capacitance materials (Hong et al. 2014; Liang et al. 2014). Bioelectricity has been generated from orange peel and other food waste-derived microbial fuel cells without chemical treatment

(Miran et al. 2016; Xin et al. 2018). The cellular imaging has been reported using highly luminescent orange juice-derived C-dots (Sahu et al. 2012). *Allium sativum*-derived C-dots have been used as in vitro; biomarker for living cells (Das et al. 2019). Residues of banana crops yielded glucose, ethanol and, a very important component, polyhydroxybutyrate, which reduced the requirement of energy and water by 30.6 and 35%, respectively (Moncada et al. 2013; Naranjo et al. 2014; Quinaya and Alzate 2014).

### 3.2.6 Hydrogen as a Fuel

It is present in abundance in the form of water and hydrocarbons. Recently, researchers gained much interest in studying hydrogen as an alternative energy source due to its emission-free burning and higher efficiency. Hydrogen has a wide range of applications as a fuel, namely domestic purposes, vehicles and spacecraft. Many techniques such as electrolytic, thermal and photolytic processes have been reported to produce pure hydrogen (Pareek et al. 2020). In spite of all these techniques, there are problems with the generation of hydrogen for commercial purposes. Natural gas has been employed as the least expensive fuel for the generation of hydrogen at commercial level (Pareek et al. 2020). The hydrogen production with the help of renewable energy resources such as sunlight and water involves photo-electrochemical and biohydrogen techniques (Kotay and Das 2008).

Hydrogen gas is a clean fuel which can be employed for a variety of applications. However, hydrogen storage is associated with some problems as compared to traditional fossil fuels due to its low density. Recently, carbon nanomaterials such as carbon nanotubes, fullerenes, graphene, activated carbon, carbon fibre, etc. have been employed in the hydrogen storage. Metal doping on carbon nanostructures may increase the hydrogen storage capacity; however, higher storage capacities can be obtained at cryogenic temperature and higher pressure (Mohan et al. 2019). Single-walled carbon nanotubes displayed enhanced hydrogen uptake due to which they can be used to fabricate tanks for hydrogen storage in FCV (Dillon et al. 1997). Carbon fibre reinforced resin matrix composite materials (CFRC) have been employed in the aerospace industry to reduce the weight of vehicle (Zheng et al. 2018). Hydrogen storage can be efficiently performed below 3 or 4 MPa above room temperature by utilizing metal hydration (Das 2016). Large amounts of hydrogen can be reversibly stored in lithium nitride in the temperature range of 170–210 °C (Chen et al. 2002). Zeolites have also been used in hydrogen storage which may be attributed to their high thermal stability, large surface area, low cost etc. (Langmi et al. 2005). Nowadays, fuel cell has been used to generate electricity by the electrochemical oxidation of hydrogen (Figure 3.2).

Fuel cell electric vehicles (FCEVs), using hydrogen fuel cell, have attracted interest of researchers in electric vehicle industries (Cano et al. 2018). Due to the drawbacks associated with the production and transportation of hydrogen fuel cells, it has been replaced by direct liquid fuel cells (DLFCs) (An et al. 2015). Recently, the hybrid fuel cells have been used in electric hybrid vehicles. A hydrogen fuel cell in combination with batteries and other control system can be used to develop a sustainable hybrid vehicle (Briguglio et al. 2010). For example, hybrid fuel cell gas turbine systems have been developed by the combination of high-temperature fuel cells (HTFCs) into cycles with gas turbines which can operate on natural gas, landfill gas, biomass syngas, etc. The above technology can appreciably enhance fuel-to-electricity conversion efficiency with reduced greenhouse

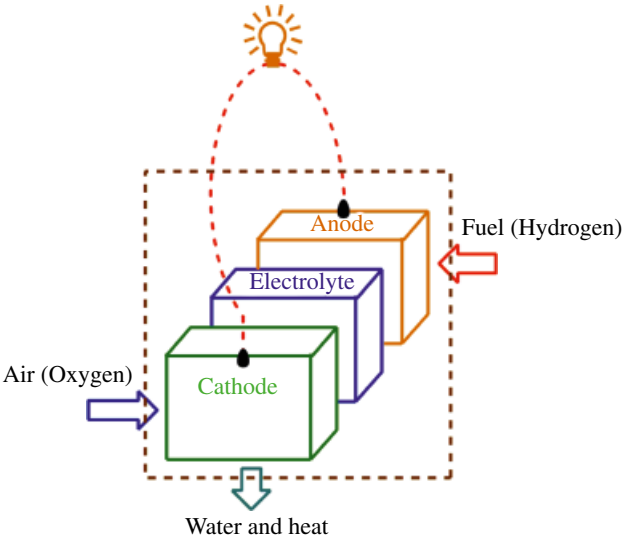



**Figure 3.2** Schematic representation of fuel cell and its working.

emissions and other pollutants (Brouwer 2012). Recently, researchers are attracted towards electrically rechargeable liquid fuel, also called e-fuel (Jiang et al. 2019). E-fuel consists of electroactive species such as organic and inorganic materials and suspended particles. Various advantages of e-fuels cells have been reported as compared to conventional liquid fuel cells (Shi et al. 2020). These e-fuel cells are emerging as a powerful technology for power generation systems in an efficient and economical manner. Recently, perovskite materials, as mixed conductors, have been employed for improving the operational efficiency of existing materials with improved cell designs (Skinner 2001).

## 3.3 Environmental Impacts

Various types of renewable energy sources can have different environmental impacts. For example, solar technologies are very expensive and space consuming. The installation of solar cells may have environmental impact on area and the topography of covered land, ecosystem and biodiversity due to the thermal imbalance of the area under application. Also, solar cell batteries are prepared by the use of harmful and toxic chemicals like heavy metals (indium, tellurium and cadmium). Although solar cells do not produce any emissions during operation, but there is always a potential risk of emissions during manufacturing, dismantling and in case of any accident like fire etc. The harmful substance from solar technologies on release may pose severe environmental threat like soil and water pollution (Turney and Fthenakis 2011). Hydroelectricity is also associated with some disadvantages like the construction of storage hydropower plants involves blocking, diverting or changing the natural course of river systems. The building of dam on a river system results in the flooding of significant amount of land due to which the flora and fauna in the river surroundings are badly affected and may result in loss of biodiversity and ecosystems.

In some cases, the flooding can also force the rehabilitation of the residential population (Anjaneyulu and Valli 2007). Disruption of natural flow of a river may pose negative impact on the natural environment of aquatic lives (Ghosh and Prelas 2011). Various migratory animals like fishes have strong impact of environment on the different stages of their life cycle (Bergengren et al. 2013). Water quality of the stored water in the hydroelectric power plant decreases due to the low concentration of oxygen and lower temperature as compared to normal river water. Also, the release of this water may have negative impacts on downstream plants and animals (Bergkamp et al. 2000). Moreover, the hydropower also results in the emission of greenhouse gases (Kumar et al. 2011). Geothermal power plant leads to the surface instability and earthquakes which may be due to the removal of water and steam from reservoirs within the earth that may result in the sinking of the land above the reservoirs (Bosnjakovic et al. 2019). Wind energy also poses some environmental impacts such as forest clearing and disruption of the natural habitat for some species. The collision of local species populations, like birds and bats, with the blades of wind turbines may result into death which may vary from one wind farm to the other (Jaber 2013). The use of traditional biomass may result in the deforestation, loss of biodiversity, soil degradation, pollution by the emissions of greenhouse gases (GHG) and loss of nutrients due to combustion of cattle dung and crop residues (Trimble et al. 1984). Hydrogen is very difficult to store and transport. Thus, a huge risk is associated with its storage.

## 3.4 Future Prospects

Renewable energy sources and innovative technologies for energy production will keep on gaining popularity in the coming years. With the more investments global and domestic industries are making to generate energy with renewable resources, the future seems to be very bright in this direction. Huge energy requirements will be fulfilled through renewable energy resources with the use of green technologies. This is the way to achieve sustainable energy system. Though the growth in renewable energy sources is remarkable, still their share in the overall energy consumption is not up to the mark. Various policies regarding that will emerge in near future. Further research should be focused to develop new and improved technologies which can reduce the cost of setting up the power plant. With the advancement towards these resources, the cost of energy sources will decline, industries would be set up, jobs will be created and standard of living will be improved, which will result in better socio-economic condition of a country. So, the alternative energy sources would serve dual purposes, i.e. cost-effective and sustainable.

## 3.5 Conclusions

Alternative sources of energy offer huge opportunities in the development of energy sector. The adequate energy supply can be maintained by integrating different technologies from diversified fields, such as solar energy, wind energy, hydropower, geothermal energy, biomass, hydrogen fuel etc. Different types of alternative resources can be developed and utilized by different countries depending on their location and availability of resources.

Various innovative techniques have been employed in various classes of renewable energy sources. Solar energy technologies have been employed to develop a variety of innovative techniques. Various PV technologies have been employed in different areas with cost-effective and enhanced technology. In case of hydropower, several modifications have been introduced in the design and operation of turbines which can reduce the mortality of fishes. Similarly, several innovations have been introduced in the generation of power using wind energy which involves the adjustment of blade size according to harsh environment wind conditions, location, etc. The geothermal energy has been integrated with other renewable sources for enhanced output efficiency. Biomass from various food and plant wastes has been utilized for the production of biomethane and bioethanol which may further be used as energy harvesters for various purposes such as transportation, power plants and composting. Recently, hydrogen has been used as an alternative resource for energy generation which can be used for various applications. Although these resources offer several advantageous due to low maintenance cost and sustainability, they are also associated with few drawbacks like dependence on the seasons and at suitable topographical regions, deforestation, loss of biodiversity and ecosystems, soil degradation, surface instability, earthquakes, difficulty in storage and transport etc. These resources can offer sustainable supply of energy with the reduction in local and global atmospheric emissions. Thus, alternative sources of energy are potential substitutes for non-renewable energy resources.

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