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RENEWABLE ENERGY AND AI FOR SUSTAINABLE DEVELOPMENT

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1 Green and Clean Energy
Current Global Scenario

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1.1 INTRODUCTION

In many countries with the revolution in industry, renewable energy (RE) became the major source energy demand over fossil fuel to fulfil their primary requirement. A total of 75% carbon emission, which was due to fossil fuel and RE, shows major effect in global climatic change. This carbon emission due to fossil fuels affected 5 million premature deaths per year. To overcome these problems, it is necessary to reduce CO_2 emissions and sip pollutant. These objectives can be accomplished with different resources and implementing it with technologies and by making policies. Two major goals can fulfil the transformation pathway. The first goal is to achieve qualitative and quantitative framework for the recognition of policies, estimate transition towards energy system and uplift sustainability development. The second goal is to promote the integration of varied energy problems and maintain global balance [1]. The international policies designed will help us to enhance social-economic developments, energy generation and distribution globally. Thus, it requires switching towards nuclear and renewable innovations globally. Solar, wind, waves, tides, geothermal and hydropower are the sources of primary energy in renewable technologies. About 11% of global primary energy came from renewable energy resources in 2019 [2]. Figure 1.1 shows the contribution of energy generation with different sources in renewable technologies since 1965 till 2020 [2].

Figure 1.2 shows changes in energy generation with different energy source along with time from the year 1985 till 2020 [2]. The generation of energy via hydropower has increased from 2000 TWh in 1985 to 4000 TWh in 2020. Apart from this, solar and wind energy generation has grown rapidly from the year 2010 onwards as per World in Data Journal. Sustainable development is also a key point towards green and clean energy. It includes social, economic and environment developments. Sustainable development motivates everyone to safeguard, preserve and boost the resources. United Nations approved 2030 agenda of developing a new roadmap of sustainable development having sustainable development goals [3]. This goal was to protect and safeguard human on the planet by providing employment, food, water, sanitization and energy. At a social level, sustainability can bring developments of people, regions and cultures, bringing equality in life, healthcare and education worldwide. Economical sustainability is dependent on the economic progress. This can be achieved by investing in and developing green businesses. Developing green industry businesses and reducing carbon dioxide emission is an approach towards environmentally sustainable development.

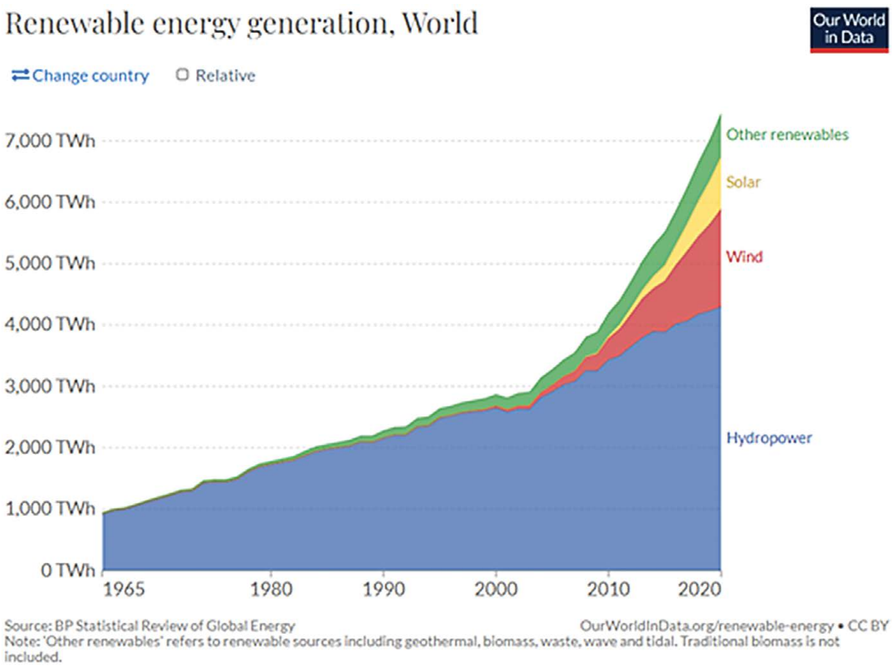

FIGURE 1.1 Primary energy generation with different energy sources.

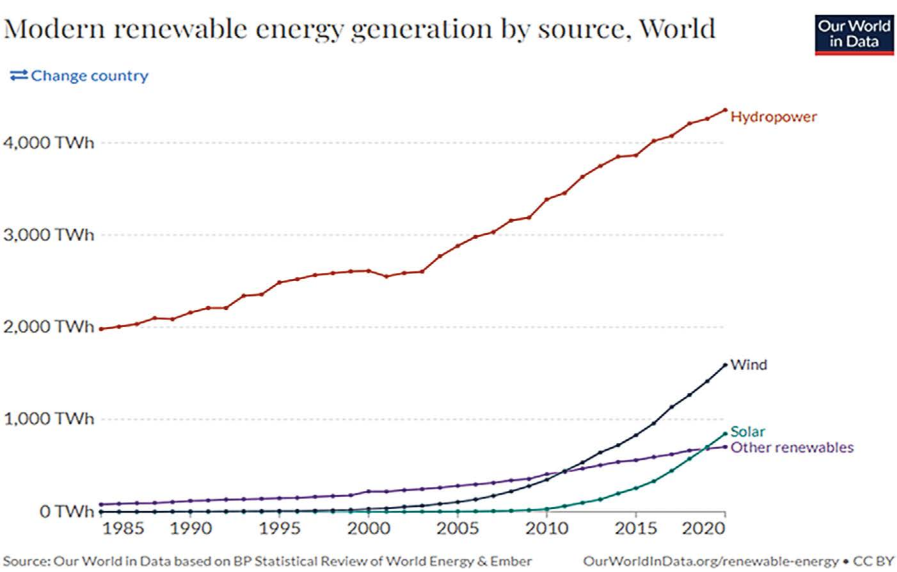

FIGURE 1.2 Change in renewable energy generation with time.

1.1.1 Objectives of the Chapter

This chapter has the following objectives:

- To study the importance of solar energy, current status of solar energy, International Solar Alliance (ISA), growth in RE and also includes international climate policies, energy transformation towards RE, leaving behind fossil fuel;
- Discuss global energy investment in terms of technology;
- And, to study the impact of COVID-19 on energy.

1.1.2 Organization of the Chapter

This chapter is organized as follows: Section 1.2 discusses the role of solar energy as well as outlines the growth of solar energy worldwide. Section 1.3 highlights the current status of solar photovoltaic (PV) capacity – worldwide, region-wise and country-wise. Section 1.4 enlightens international climate policies like international efforts for climate change and Nationally Determined Contributions. Section 1.5 illustrates International Solar Alliance in terms of power system transformation, power system operator survey towards global energy transformation and status of power system transformation. Section 1.6 discusses global energy investment in terms of investment by technology and investment by region. Section 1.7 focusses on employment in renewable energy. Section 1.8 stresses on the impact of COVID-19 on energy and Section 1.9 concludes the chapter with future scope.

1.2 ROLE OF SOLAR ENERGY

Solar energy is abundant and inexhaustible in nature. It is a green and clean energy source. All life on this universe is dependent on the sun [4]. The radiant energy of sun provides heat and light by the fusion of hydrogen into helium at its core [4] known as solar radiation. A total of 50% of the solar radiation reaches the earth's surface, while the rest is absorbed in the atmosphere or thrown back by the clouds [4]. The solar radiation can be captured and turned into useful forms of energy. The sun energy is generated due to nuclear fusion at the core of the sun. The earth receives this energy in the form of sunlight. This sun energy is beneficial in production of electricity due to photo-voltaic effect in the same way as green plant use sun energy to produce their food known as photosynthesis. The sun can contribute 1,000 times more energy than required by the world; however, only 0.02% of the total energy is being used currently [5, 6]. Utilization of solar radiation can be done for lightening the homes, buildings, street and heating the surroundings by generating electricity from it. The major concern towards solar energy is the climatic change. Production of electricity with solar radiation is clean and green electricity compared to that generated from fossil fuel, i.e. free from air, water and environment pollution with zero global warming and threat free to public health. According to the US Department of Energy, the amount of solar radiation reaching the earth's surface is more than enough to fulfil the requirement of energy globally for a period of one year [4]. The amount of power generated by solar radiation and stored within half month is equal to the sum of energy stored by coal, oil and natural gases in all planets. Once the electric power energy is harnessed for solar radiation, fuels are free.

1.2.1 Growth of Solar Energy Worldwide

Growth of solar energy worldwide with PV techniques was exponential from 1992 to 2018 as shown in Figure 1.3. This duration was called as solar PV era which evolved from small scale and spread all over to larger market as a mainstream electricity source. The solar PV system was potentially recognized by the subsidy programmes regarding tariffs. This was implemented by many governments to provide economic incentives for investments. For many years, Japan and European countries took the advantage of the subsidy and made progress in the economy. In 2011, the United States and China made the Solar Roof project for enhancing PV deployment with five-year plan energy generation. The deployment of PV system via bottom up market strategies is very powerful. This strategy concentrate towards technologies for providing rooftop energy services i.e. helpful for house hold goods and for commercial process technology in United States via 2030. The market of utility scale plant came into existence in the early 21st century with generation and distribution applications. The growth of PV worldwide is shown in Figure 1.4. Till the year 2015, 30 countries generated electric power and distributed it at a low cost of electricity, which is quite less than or equal to the energy supplied from the grid. The United State will be on top in solar market. Next will be Japan and then Germany. At Present China is the world largest manufacturer of solar PV panels in manufacturing PV module and

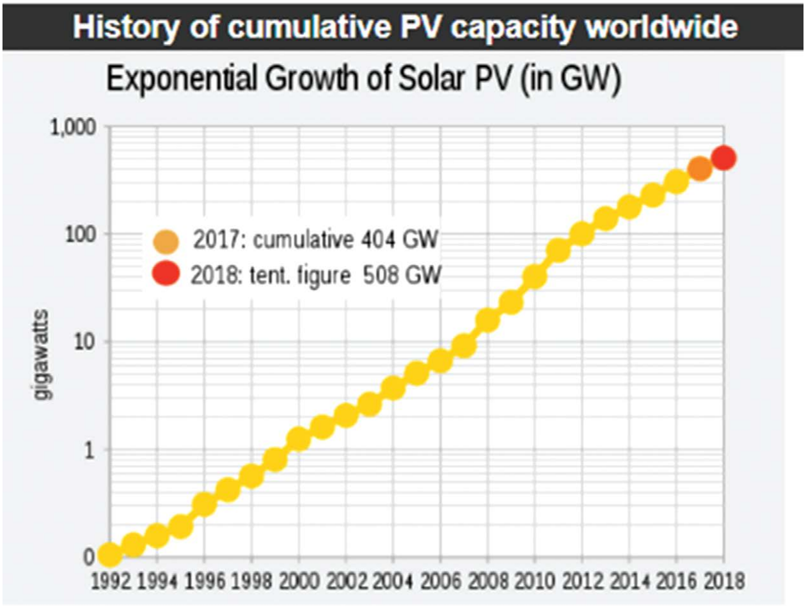

FIGURE 1.3 Exponential growth in solar photovoltaic energy.

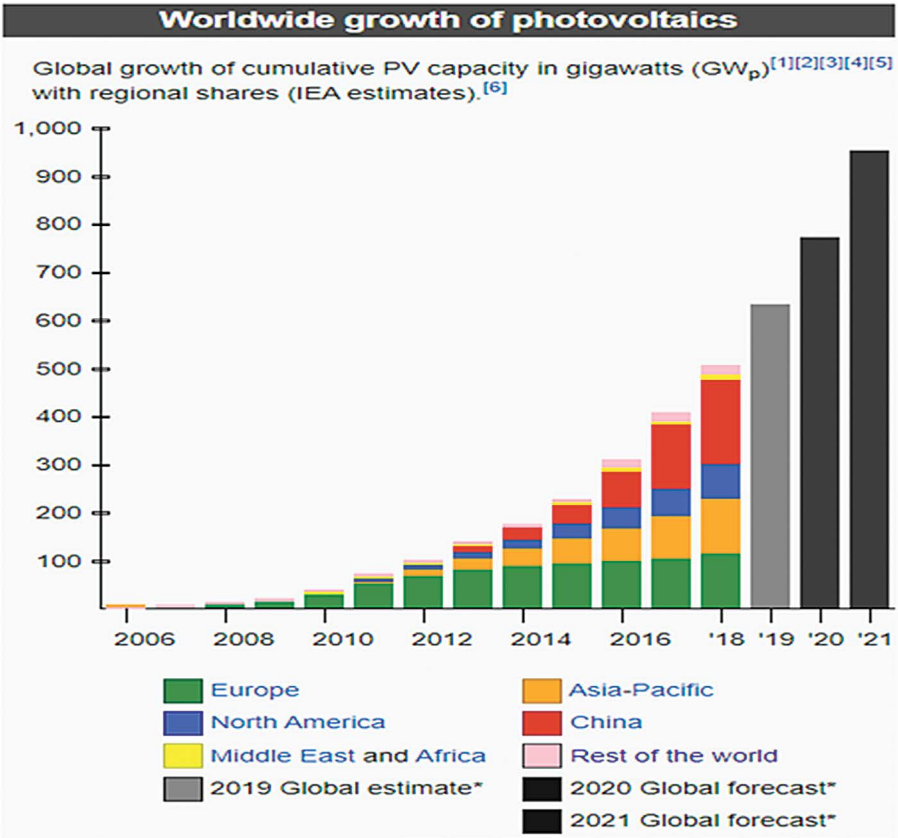

FIGURE 1.4 Growth of photovoltaic energy worldwide.

is also a leading country in electricity generation since 1950. Installation of solar PV globally reached about 512 GW in 2015 including 35%, that is 180 GW was utility scale plant. Solar PV power provided 7%–8% of domestic electricity consumption in Italy, Greece, Germany and Chile in 2018. A total of 14% of electricity generation in Honduras made a bench mark of largest production, 11% in United Kingdom, 4% in Spain and, approximately, 2.55% in India and China.

1.3 CURRENT STATUS OF SOLAR PHOTOVOLTAIC CAPACITY

The current status of installation capacity is categorized worldwide, regional-wise and country-wise.

1.3.1 Worldwide

PV installation capacity was enhanced by 95 GW in the year 2017. The total installation capacity crossed 401 GW the same year, supplying 2.1% of the total power

TABLE 1.1
Photovoltaic Stations with the Maximum Installation Capacity across the World

Year	Name of Photovoltaic Power Station	Country	Capacity (MW)
1982	Lugo	United States	1
1985	Carrisa Plain	United States	5.6
2005	Bavaria Solarpark (Mühlhausen)	Germany	6.3
2006	Erlasee Solar Park	Germany	11.4
2008	Olmedilla Photovoltaic Park	Spain	60
2010	Sarnia Photovoltaic Power Plant	Canada	97
2011	Huanghe Hydropower Golmud Solar Park	China	200
2012	Agua Caliente Solar Project	United States	290
2014	Topaz Solar Farm	United States	550
2015	Longyangxia Dam Solar Park	China	850
2016	Tengger Desert Solar Park	China	1547
2019	Pavagada Solar Park	India	2050
2020	Bhadla Solar Park	India	2245

consumption globally [7, 8]. Table 1.1 shows the PV stations with largest capacity worldwide from 1982 to 2020 with its generation capacity [9].

1.3.2 Regional

Among regions, Asia is one of the rapidly growing regions with 75% of the global installation capacity. In 2017, China itself is producing more than half of the world-wide consumption. Total installation capacity of the Asian region is 401 GW [7]. Europe declined to 28% global capacity, America 19% and Middle East 2%. Installation capacity of the European Union was twice or more than China and 25% more than the United States.

However, with respect to per capita installation, the European Union has more than twice the capacity compared to China and 25% more than the United States [10]. European fulfilled 3.5% electricity demand and 7% peak electricity demand by solar PV power in 2014 [9].

1.3.3 Countries and Territories

Solar power plant was installed as an alternative conventional energy source in many countries as well as territories. Table 1.2 shows the different countries and territories with their solar PV capacity.

China is the world's leading country in the generation of solar power with an installation capacity more than 200 GW at the end of the year 2019 [11]. It also has the biggest market for solar PV and solar thermal energy. In the past five years, more than half of PV was marketed by China with the help of suitable policy makers,

TABLE 1.2
Solar Photovoltaic Capacity (MW) Installed in Different Countries and Territories [9]

	2016		2017		2018		2019		2020	
Country	**New**	**Total**	**New**	**Total**	**New**	**Total**	**New**	**Total**	**New**	**Total**
China	34,540	78,070	53,000	131,000	45,000	175,018	30,100	204,700	49,655	254,355
European Union	101,433		107,150	8,300	115,234	16,000	134,129	18,788	152,917	101,433
The United States	14,730	40,300	10,600	51,000	10,600	53,184	13,300	60,682	14,890	75,572
Japan	8,600	42,750	7,000	49,000	6,500	55,500	7,000	63,000	4,000	67,000
Germany	1,520	41,220	1,800	42,000	3,000	45,930	3,900	49,200	4,583	53,783
India	3,970	9,010	9,100	18,300	10,800	26,869	9,900	35,089	4,122	39,211
Italy	373	19,279	409	19,700		20,120	600	20,800	800	21,600
Australia	839	5,900	1,250	7,200	3,800	11,300	3,700	15,928	1,699	17,627
Vietnam		6		9		106	4,800	5,695	10,909	16,504
South Korea	850	4,350	1,200	5,600	2,000	7,862	3,100	11,200	3,375	14,575
Spain		4,669		4,688		4,707		8,711	5,378	14,089
United Kingdom	1,970	11,630	900	12,700		13,108	233	13,346	177	13,563
France	559	7,130	875	8,000		9,483	900	9,900	1,833	11,733
The Netherlands	525	2,100	853	2,900	1,300	4,150		6,725	3,488	10,213
Brazil			900	1,100		2,413	2,138	4,595	3,145	7,881

industries and the subsidies by the government help in reducing the solar power cost. In the field of solar water heating, China is accountable for generating 70% total world energy requirement capacity. China has its future mission to hit the target of solar capacity of 1300 GW by the end of 2050 [11].

Japan is on second position in solar market, expanding solar power since 1990s. Installing 8 GW solar powers in 2017, it has reached over 50 GW cumulative installation capacities by the end of the same year [9]. Now the country is supplying 2.5% of electricity demand annually.

India holds third position in the world in solar power. In 2017, India made a record of 9255 MW with another project of 9627 MW which was under development [11]. National Solar Mission was launched in 2010 to produce 20 GW power till 2022 under the action plan on Climatic Change. This target was achieved in 2018 only, that is four years before the target date. After achieving 20 GW, Prime Minister Shri Narendra Modi was motivated and enhanced the solar capacity to 100 GW and overall renewable capacity to 175 GW by 2022.

1.4 INTERNATIONAL CLIMATE POLICIES

Climate change is a major global challenge for the 21st century. The earth's surface temperature is continuously increasing due to the use of fossil fuels releasing CO_2 and other gasses into the environment resulting in global warming. The Intergovernmental Panel on Climate Change (IPCC) reported the finding of the global climate change research in the Fourth Assessment Report held in 2007 [12, 13]. During its Fifth Assessment Report in 2014, the conclusion of the research was the same as the previous report, that is "to keep global warming below 2°C, emissions of carbon dioxide (CO2) and other greenhouse gases (GHGs) must be halved by 2050".

1.4.1 International Efforts for Climate Change

In 1992, an agreement was made by the international community under UN Framework Convention on Climatic Change (UNFCCC) to preserve the environmental concentration of CO_2 and other greenhouse gases at a certain magnitude to prevent further dangerous interference with the climate system [12]. In their next conference, UNFCCC made emphasis on reducing greenhouse gas emission for industrialized countries. This agreement was reinforced in 2005 and the undertaking was committed to being effective till 2020.

1.4.2 Framework Convention on Climate Change

Conference of the Parties (COP21) in 2015, Paris made an agreement with three major goals for all countries [12]. First was to limit global warming to less than 2°C as compared ideally to 1.5°C at the pre-industrial level. This goal would lower the risks on health issues and impacts of climate change on the environment. Second goal was to adapt the climatic change and lower the emission in order to prevent food production from risk. Last was to align the finance flow and ensure the reduction of

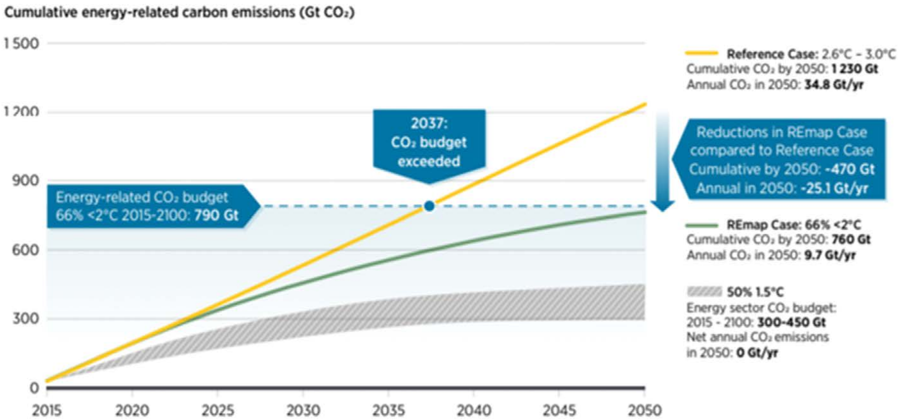

FIGURE 1.5 Budget till 2050 for reducing CO_2 emissions globally [14].

greenhouse gas emission and more durability towards climate change. This agreement was enforced on November 4, 2016 [12, 13] national climate policy. Germany and EU maintained the above-mentioned agreement limiting the global warming below 2°C with pre-industrial times. The German government forced for organizing annual Petersburg Climate Dialogue [13]. In 2009, Federal Chancellor, Angela Merkel, launched the Petersburg Climate Dialogue which reveals the climate negotiation in Copenhagen [13]. This was in-between climate summit, bringing environment ministers together from developing, developed and newly industrializing countries for open discussion. This open discussion was to achieve faster progress in international climate negotiation. The goal to achieve environment temperature rise below 2°C was a big issue [14]. Overall emissions are to be reduced further by 470 Gigaton (Gt) till 2050 [14] compared to current and planned policies (business-as-usual) to hit the target. The mission to reduce CO_2 below 2°C related to energy globally budget is shown in Figure 1.5 [14].

1.4.3 Nationally Determined Contributions

Australia submitted an emission reduction policy which was known as NDC under the Paris Agreement Act [15]. The first NDC is available on the UNFCCC platform which includes the following points [15]:

i. 2015 NDC includes commitment for the reduction of emissions from 26% to 28% below that was in 2005, by the end of 2030.
ii. 2020 NDC includes confirmation of the target set in 2015, and amendment of new plans and operations.
iii. 2021 NDC includes bond for 100% free carbon emission by the end of 2050.

By the end of 2025, Austria will submit next NDC to UNFCCC which will include the target set till 2030 [13].

1.5 INTERNATIONAL SOLAR ALLIANCE

ISA was launched during Paris Climate Conference, 2015, to upgrade solar technologies especially for those countries having high solar resources but under-developed electricity access [15]. Since Austria was the founder of ISA, it promised to share its expertise regarding solar technology and generation of power via providing training and webinars [15]. The founder of ISA also promised to provide library of tools and resources for policy development through Clean Energy Solution Centre [15].

1.5.1 Power System Transformation

Many countries in the world are moving towards the electricity system through renewable energy and other low carbon emission energy resources to fulfil the economic, environment and reliability goals [14]. In achieving this goal government, research and educational institutes are facing challenges in gaining knowledge and applying this elegant knowledge to transform the power system [16, 17]. To overcome these challenges and barriers towards different countries requires a global consortium, that is Global Power System Transformation (G-PST) Consortium [16, 17]. The G-PST Consortium provides coordinated, holistic support and knowledge infusion for system operators pursuing clean energy transitions, including performing cutting-edge research; providing implementation support for world-class engineering and operational solutions; supporting workforce development; building and disseminating open-access data and tools; and accelerating localized technology adoption, standards development and testing programs [16, 17]. There are five areas where this Consortium will take action while reinforcing the following initiatives:

i. **System Operator Research and Peer Learning and Presentation**
Application-based research should be done to produce best solutions to the system operations and developing awareness through learning.

ii. **System Operator Technical Assistance**
Training should be given to technical staff through workshop.

iii. **Foundational Workforce Development**
Curriculum at university level should be changed to create manifold workforce for future and developing technical skills to the system operators.

iv. **Localized Technology Adoption Support**
Every country should adapt modern innovations of power system through testing programs and skilled development workshops.

v. **Open Data and Tools**
With the help of tools and data, various plans, operations and real-time systems can be monitored.

This transition took place with speed globally with the increase in flexible renewable energy (FRE), inverter-based resources (IBRs) and distributed energy resources (DERs).

1.5.2 Power System Operator Survey Towards Global Energy Transformation

IEEE SA and the IEEE Power and Energy Society are working together under the Global Power Systems Transformation Consortium (G-PSTC) to evaluate their opinions towards next-generation energy (e.g. renewables, energy storage, DER, energy efficiency and grid modernization, etc.) to fulfil their basic needs [18]. The survey was done in two parts [18]:

i. Priorities towards system operator technical strategy.
ii. Enabling key standards and their uses.

In this survey, 39 responses were about the query of the system operation with 78 respondents. The representation of the global respondents was: the United States (16 responses, i.e. 41.9%), Asia Pacific (14 responses, i.e. 35.9%), Europe (5 responses, i.e. 12.8%), Canada (2 responses, i.e. 5.1%) and Latin America (2 responses, i.e. 5.1%) [18].

1.5.3 Status of Power System Transformation

Transformation of power system means power system flexibility. In other words, we can say that energy transition to boost system flexibility is not simple. Power system flexibility encompasses all relevant characteristics of a power system that facilitates the reliable and cost-effective management of variability and uncertainty in both supply and demand. It is a lively process, occurring in different places with different installation capacities and at different speeds globally. This change in power system has diverse pilots, that is driving new technologies, policy making goals, social economics change, financial goals and business development techniques [19]. For customer satisfaction it is required to design qualitative and quantitative policies which can help them in implementing legal document and infrastructure for developing the utility resources. This exercise will be beneficial toward rapid power transformation and will retain for decades. Investment is flowing increasingly not just towards new generation technologies like renewable energy and cleaner conventional generation but also towards an ecosystem of smarter grids, energy efficiency technologies, demand-side flexibility, storage, electric vehicles and integrated heating and cooling systems [19]. These changes can be seen globally today. Crystal clear vision of transformation of the RE power system is still limited.

Alteration in power system transformation is visible in 11 areas [19], which include Environmental Stewardship, Transmission Systems, Distribution Systems, Transmission-Distribution System Interface, Finance, Markets, Pricing, and Cost Allocation, Static and Dynamic Load, Flexible Generation, Integration with Heating and Cooling and Integration with Transport, Energy Storage, Microgrid [19].

1.5.3.1 Environmental Stewardship

Environmental steward is the step taken by the individual or group with the motive to protect and take care of the environment from the environmental hazard. Keeping in view about the climatic change, quality of environmental gas/air, water death, ecosystem challenges along with low carbon emission technologies, a new boarder electricity plan towards energy sector is set [20]. These electricity planning process and policy plans will help us to proceed towards renewable power energy sector and fulfil the standards and regulation of the environmental goals [21].

1.5.3.2 Transmission Systems

With an emerging trend in the field of renewable energy, both wind and solar energy move parallel with the growth of transmission infrastructure. The installation location of these energy sites is usually far away from consumers or transmission sections. RE can provide better use of generation and transmission resources with well-organized new transmission lines [22]. Reactive and proactive approaches are the two best ways for expansion of transmission section. Reactive approach relates to the commitment of RE projects while proactive approach relates to the purpose of guiding the efficient growth of the power system [22].

1.5.3.3 Distribution Systems

The distribution system is the last stage of an electric power system. It is located near or inside a village, town or industrial area [23] and distributes electricity to the consumer received from the transmission system [23]. The distribution network is fully capable of balancing the generation and control over flexible and dynamic load. It is also engaged in two-way power flow, that is generation distribution and storage. The distribution network interacts and keeps control on both side operators, that is distribution system operator and transmission system operator [19]. Distribution system operation will monitor and collect the data and model their distribution system for further use.

1.5.3.4 Transmission–Distribution System Interface

The electric transmission and distribution systems are two different power systems at different locations far away from each other. Generation of electricity connects the transmission system for transporting the electricity to the distribution system for the customer to avail the electricity. The transmission–distribution interface becomes a junction of economic value, giving rise to a new electric market and technical control electric power system [23]. Relationship of distribution connected generators, PV and others to the wholesale market, and the data transfers and coordination [24].

1.5.3.5 Finance, Markets, Pricing and Cost Allocation

Finance is an important part of power system function. Market value, low cost of the electricity is evolving in support of renewable power system transformation. Innovation emerged in four different modes. These are as follows [19]:

i. Upcoming with new financial investment policy into power sector.
ii. Investing finance according to priority areas.
iii. Involving smart technologies to enhance power system efficiency and reducing carbon emission.
iv. Developing new market strategies to maintain the latest system efficiencies and providing power system flexibility.

In the past, power sector investments were dependent on the return of investments (ROI), set by the regulators. Finance gained by ROI by the governments and third-party project developers were having sufficient finance to invest on the expansion of power sector. Thus, new markets and financial innovations pop up with investments in clean and green energy market [19].

1.5.3.6 Static and Dynamic Load

Static load is power efficiency and dynamic load is future power demand. Both the loads are economical to utilize and control it. Various innovations are used to make the load more efficient and dynamic. These technologies make use of grid services and operation. Smart meters are used for fixing new prices of electricity for customer satisfaction. This results in load adjustments or time management response to system condition. These adjustments take initiative at customers' end or as signal price automated response. Thus, opening the sources and pathways for system planning, operation and investment [19].

1.5.3.7 Flexible Power Generation

Before renewable energy era, power system planning and operations were based on three types of energy generations, that is base-load, intermediate and peak [25]. These operations were planned according to the utilization of power plant and its cost throughout the year. The conventional base-load energy generators were coal which fulfilled the fixed amount of energy, considered as fixed source power system. Power generated from the conventional sources easily fulfils the electricity demand, while the solar and wind energy is dependent upon the weather conditions and is highly variable. The energy generation with low tariff is with wind and solar energies, but these power plants are never considered as base-load depending upon their duration, rather operate for some hours of the year and resemble as intermediate energy generation power plants. Figure 1.6 [19] shows the impact of conventional and transformed power systems.

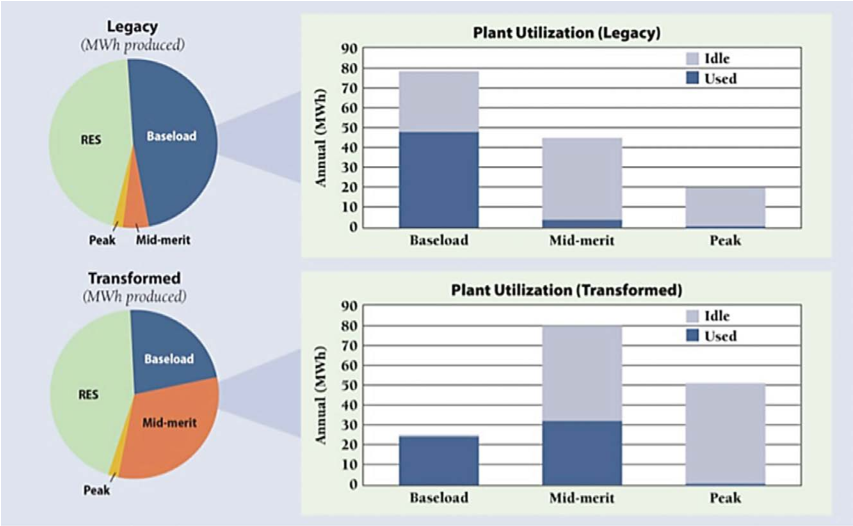

FIGURE 1.6 Impact of conventional and transformed power systems.

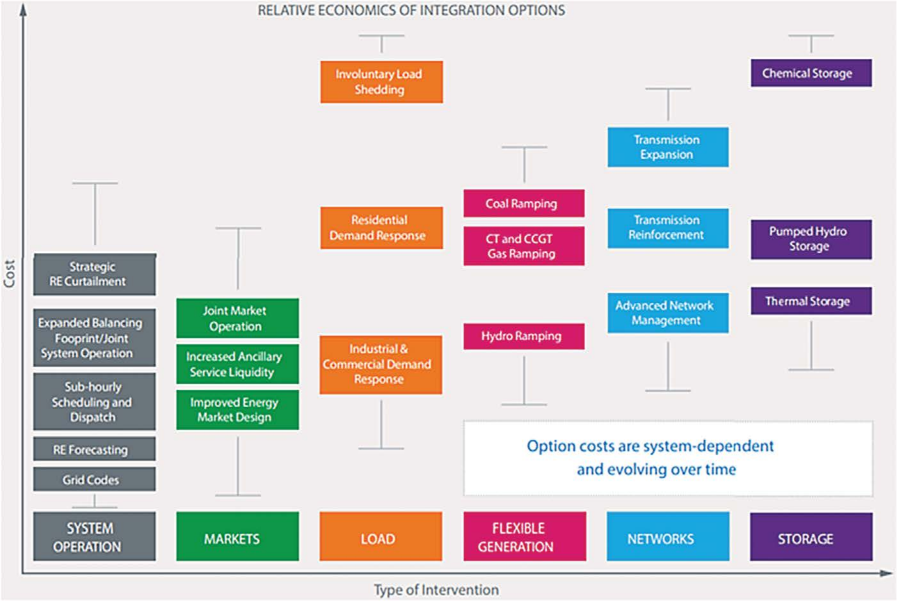

FIGURE 1.7 Flexibility in power system of variable renewable energy [26].

The weather conditions for renewable energies (solar and wind) are very challenging for making a balanced supply of electricity and its necessary demand. But flexible renewable energies have many economic and environmental advantages in the coming days, as shown in Figure 1.5. Interconnect grid will ease the problem of flexible demand. Interconnects in grids can also reduce the wholesale electricity price. One example of France is given, that is during 2016 and 2017, nuclear capacity was very less to fulfil the electricity need of the citizen. The country imported energy from Britain, Germany and their surrounding neighbours, reducing the need of gas power plant. This showed that interconnect is a big advantage and many nations are willing to adopt this technology. The flexibility in power system of variable renewable energy (VRE) is shown in Figure 1.7 [26].

1.5.3.8 Integration with Heating and Cooling

Energy system integration refers to associating numerous energy carriers and storage solutions with each other for strong, authentic and well-planned energy system. This involves heating, cooling, transport and export of electricity and gas. Strong benefits are involved with increased system flexibility with dispatch-able loads and stored energy. This flexibility allows adding more renewable energy with low cost and lesser peak system load. Broad integration with heating and cooling options contains electric power with RE power, renewable-based gases (including "green" hydrogen), use of sustainable bioenergy and the direct use of solar and geothermal heat. The use of green energy will make the future of the energy system free from carbon emission.

1.5.3.9 Integration with Transport

Globally, only 4% of RE is shared in the transport division by the end of the year 2015 [14]. In many countries' biofuels, mostly bioethanol and biodiesel are dominant energy resources in renewable energy. Electricity is the biggest option to reduce CO_2 emissions in renewable energy. In transforming power system, non-conventional energy system will surely reduce carbon emission. Renewable energy sources are abundant in nature having fluctuation outputs, so balance is to be made in between electricity demand and its supply [19]. Transportation sectors are moving towards electric vehicle or hybrid. Electric vehicles (EV) are replacing oil in light vehicle reducing carbon emission [27]. These EVs provide storage to integrate a transportation management system, fulfilling the time of generation with the load [27]. Figure 1.8 shows the change in utilization of renewable energy from 2015 to 2050 in transport sector globally [14].

1.5.3.10 Energy Storage

Energy storage system is the capability of storing energy and power and are able to maintain energy for long time before it is transformed into useful work.

The battery storage system is an example of it which can store power from watt to mega-watt.

The main advantages of energy storage system are availability of energy on time, storing large amount of energy and for transportation.

The current transformation of flexible power system across the world is a starting opportunity for many countries towards VRE, providing electricity services at the reduced cost along with the challenges towards climatic changes [28].

Excessive use of renewable energy is leading towards access to electricity, and storage is the major factor rising towards the renewable energy power system. Energy storage is necessary for integrating FRE, that is solar PV and wind or other sources of flexible power system in the weak grid areas [29]. Energy storage has changed the

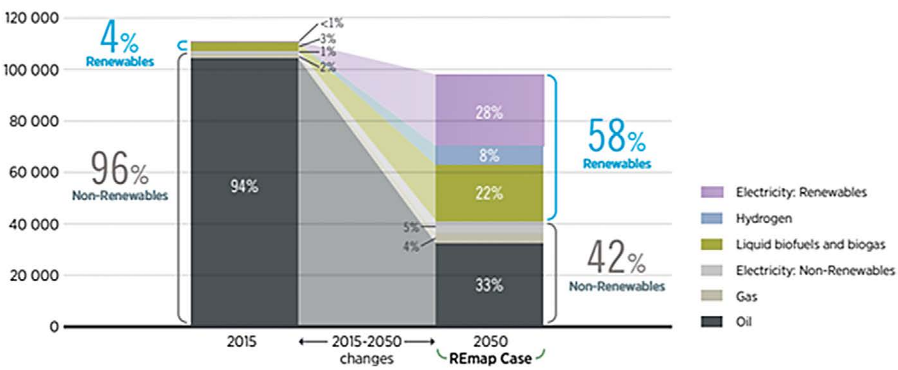

FIGURE 1.8 Renewable energy consumption in transport sector globally from 2015 to 2050.

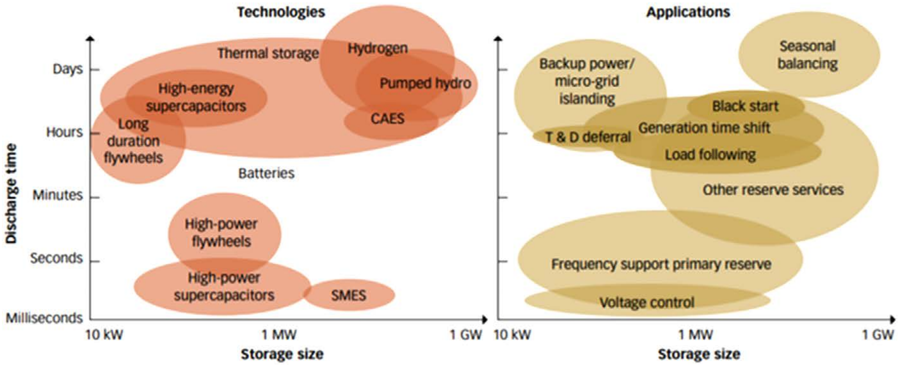

FIGURE 1.9 Energy storage technology with its storing capacity and applications.

universal use of electricity at the international level, reducing CO_2 in the environment. This results in excess of electricity in remote and rural areas [30]. The total storage capacity worldwide is approximately 200 GWh in 2019. The main storage technology used is pumped hydropower (mechanical), electrochemical (batteries) and thermal [29]. In hydropower pump, water is pumped, heated and the steam of hydroelectric generator is stored and released when required. A total of 91% was the electric storage capacity worldwide in 2019 using pumped hydro technology, 5% using electrochemical batteries and 3% with thermal storage technology, while hydrogen and compressed air technology were at lower portion [30]. Pumped hydropower energy system was used in power grids while thermal storage is widely used for cooling and heating buildings, thus reducing carbon emissions. Among all energy storage technologies, electrochemical energy storage is fast growing in the market of renewable energy but is still dominated by electrical vehicles as a consumer application. Figure 1.9 shows different energy storage technologies with its storage capacity and their applications [31]. Battery-based solutions are modular, easy to change, fast respond and reduced cost.

Energy storage at large scale is at grid level energy storage system. This is a necessary step taken for stabilizing the power generation, supply, distribution and its utilization at the customer end [31]. Small storage energy management is easy and modular giving rapid response towards flexible RE installation and its utility. Many other types of battery technologies are used; these are lead–acid, nickel–cadmium, nickel–metal hydride batteries. With the decreasing costs of lithium-ion batteries (LIB) [32], they are used as stationary Battery Energy Storage Systems (BESSs), especially for mobile applications [31]. According to IEA's World Energy Outlook 2020, under the Sustainable Development Scenario, the battery storage capacity can enhance from 6 GW in 2019 to 550 GW by the end of the year 2040 [31, 33].

According to IRENA 2019 report, by the end of 2030, the installation cost of the flow battery storage system will reduce by 66%, high temperature batteries by 50%–60%, flywheel by 35% and compressed air energy storage by 17% [31] as shown in Figure 1.10.

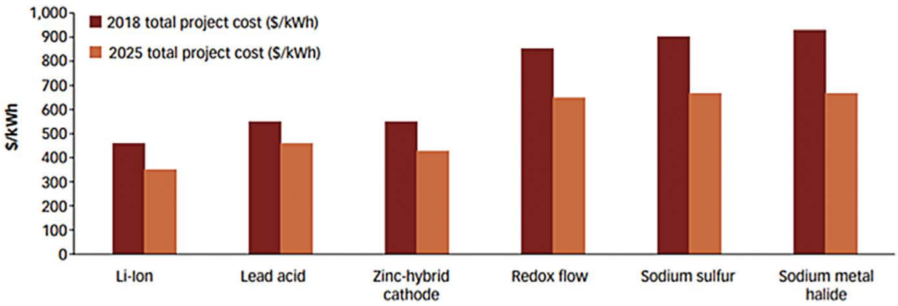

FIGURE 1.10 Energy storage technology and installation cost from 2018 to 2025 [30].

1.5.3.11 Microgrid

Microgrid is a grid-connected setup for flexible energy resources installed within the locality or outside for reliability, resilience and operational economics [34]. It is also referred to as a local group of interconnected loads and distribution within a specific region defining electrical boundaries. Microgrid can get connected or disconnected from the main grid as per the requirements and economic conditions. Renewable energy sources have fulfilled the requirement of energy demand, challenges of climatic changes and contribution towards the sustainable energy development. The integration of flexible energy system is carried out and the distribution in electricity is done through microgrid [33], exchanging information between the consumers and generation-distribution centres. In other words, the energy management system of microgrid maintains the information and controls the generation-distribution system and supplies electricity at a low operational cost [35].

In future, microgrid technology will be used globally, especially in Asia and the Pacific region and North America. Their installation capacity will grow five times from 2018 to 2027 [34], as shown in Figure 1.11. Microgrid is aiming towards infrastructure reliability, investments and achieving green and clean environment free from carbon emission. Residence of the community is the primary customer and

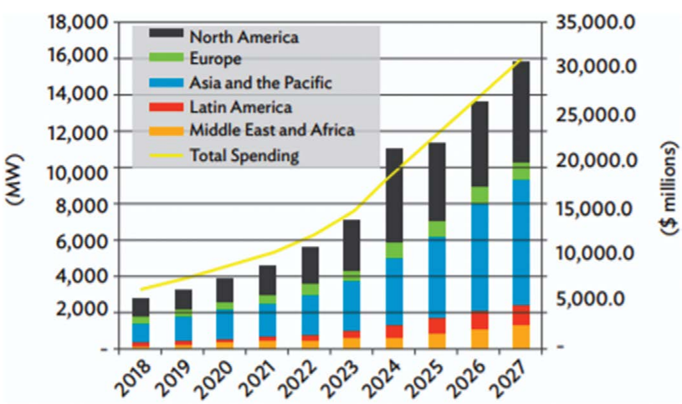

FIGURE 1.11 Installation capacity of microgrid from 2018 to 2027 [34].

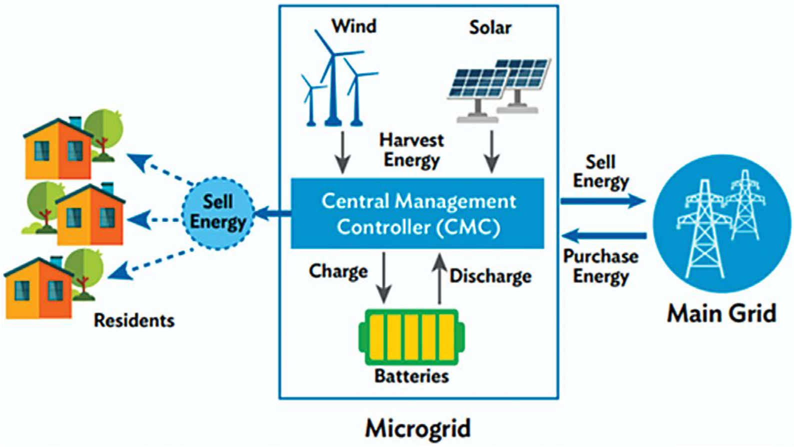

FIGURE 1.12 Microgrid operation [34].

their requirements are fulfilled with affordable cost and security. An overview of operation of the microgrid [34] is shown in Figure 1.12. A microgrid is a group of interconnected loads and DERs within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island mode. Advantages of microgrid are reliability, security, reduced electricity cost, clean and green energy which helps to maintain zero carbon emission, can help deploy more zero-emissions energy sources, make use of waste heat, reduce energy lost through transmission lines, help manage power supply and demand, and improve grid resilience to extreme weather.

1.6 GLOBAL ENERGY INVESTMENT

Global energy investment has grown to 1.9 trillion USD in 2021 [36, 37]. A 10% jump in the renewable energy investment in 2021 since 2020, getting out from the crisis level of COVID-19 pandemic [35], shifting towards RE electricity and moving far away from conventional fuel production. According to IEA report, renewable energy has attracted 70% of the total $530 million global energy investment in 2021 for new power generation capacity [36, 37]. Investments are done depending on the present capital spend in energy supply capacity (fuel production, power generation and energy infrastructure) and energy end-use and efficiency sectors (buildings, transport and industry) [36]. New enhanced technology in solar and wind has shown rapid improvements towards electricity generation, resulting four times better electricity production rather than same amount of dollars spend 10 years ago. Figure 1.13 shows global energy supply investment in different sectors of energy [36].

Apart from remarkable growth renewable energy, China has tremendous growth in coal-based power production in December 2020 [37]. Overcoming the risk and hindrances towards finance, climatic finance played an important role in bridging the financial gap and moving towards investment from private sectors to renewable

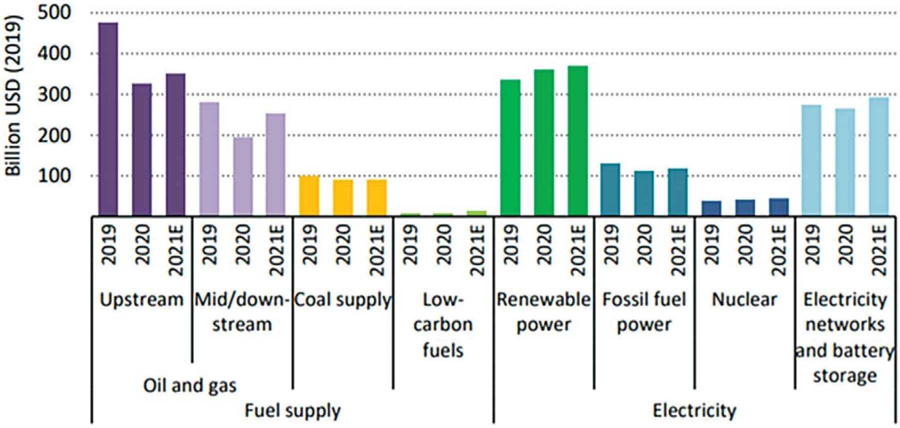

FIGURE 1.13 Global energy investment in different energy sectors [36].

energy power sectors [38]. Figure 1.13 shows annual investments in renewable energy using different technologies [38, 39].

1.6.1 Investment by Technology

Solar PV and wind onshore were superior in renewable energy sector in the year 2017 and 2018, committing of spending 77% of the total finance [39, 40]. Huge investment in RE technologies is due to their appropriate policies, improvement in manufacturing technologies, progress in short time period and competition in the market. Investments by technology is shown in Figure 1.14 [38, 39]. From 2014 to

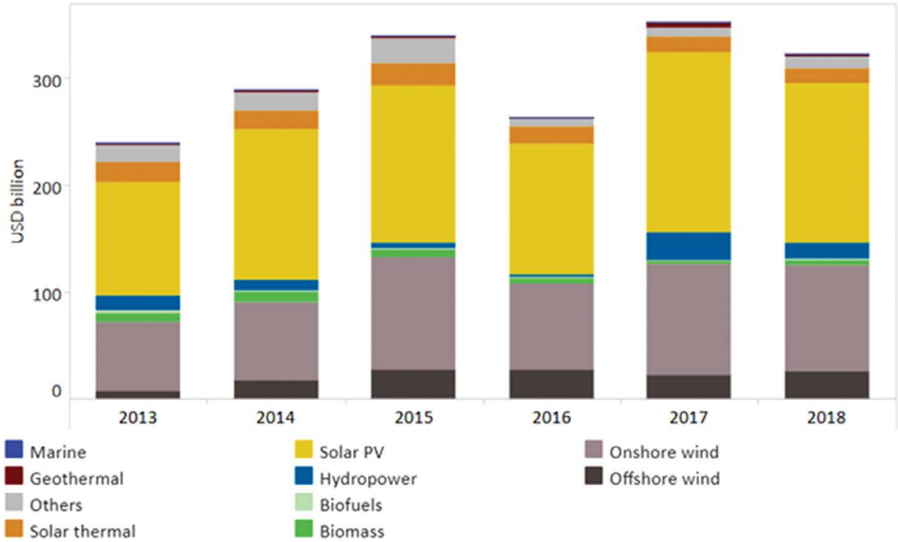

FIGURE 1.14 Investments by technology [38, 39].

2018, investment in offshore wind was alluring and having an average growth of USD 21 billion per year globally and played an important role in reducing CO_2 emissions in the environment.

1.6.2 Investment by Region

China was on the top in renewable energy (solar PV and wind) market, having 93% investment in renewable energy from 2013 to 2018, while Asia and the Pacific region invested approximately 32% of global energy finance commitment in the financial year 2017–2018 [39]. Continuous investment in renewable energy in the United States boosted up the number of countries of the Organization for Economic Co-operation and Development (OECD) located in the Americas [39]. Combining all regions in the financial year 2017–2018 enhanced 22% of global investment in RE with an amount of USD 82 billion peak in 2018. Western Europe also invested USD 51 billion in 2017–2018 [39], becoming 15% of the total investment in the RE sector. In 2017–2018, Asia has a down fall of 53% in renewable energy investment as compared to the year 2015–2016, which may be due to decrease in solar energy investment in Japan.

1.7 EMPLOYMENT IN RENEWABLE ENERGY

Global financial system is dependent on the strength of energy generation and distribution. Everyday life is completely dependent on energy, based on un-replenishable resources, mainly fossil fuels. These conventional energy resources are used at a faster rate than being developed, contributing to CO_2 emissions into the environment. Our dependency on electricity to deliver power for our homes, offices, hospitals and organizations requires an essential shift towards renewable and sustainable power. This transition of energy towards renewable energy power ought to produce new jobs, imparting millions of people global with access to sustainable electricity, in parallel, decreasing CO_2 emissions from the environment. Jobs are the foundation of financial and social improvement. To analyze the exact employment due to productive use of electricity is not an easy task. A survey was done and a review of 50 studies effecting the production of electricity was observed. The analysis of this study shows an increase in 25% in employment, 30% increase in remuneration and 7% increase in school enrolment [40]. They permit humans to earn an income and paint their life out of poverty to reap better livelihoods. Eighty one percent, that is, 163 million of the 200 million human beings are unemployed globally and 1.4 billion are self-employed but are at risk [41]. Accordingly, the advent of satisfactory job is a priority goal for growing countries and a fundamental factor of overseas help. However, creating new jobs is a complex mission, with considerable number of investment and sector-specific factors affecting the final success of policies and plans. NDCs have achieved huge attention from countries because of the 2016 Paris Agreement, upholding 189 countries till 2020 [42].

NDCs have committed and laid the foundation of maintaining the global temperature below 2°C or further below up to 1.5°C to diminish climatic change. Reducing GHG emissions through improving renewable strength era could also make contributions to job introduction and become a using force of countries' financial growth. Climate mitigation effort should be advantageous locally in addition to the worldwide blessings of the GHG emissions reductions and consequently, might be the catalyst for setting greater formidable NDC goals. Reducing GHG emissions through improving renewable strength era can also contribute in introducing new jobs and becoming a dynamic strength of countries' financial growth. According to the International Energy Agency (IEA), the RE area contributes to 42% of worldwide electricity-related CO_2 emissions and, simultaneously, RE electricity era is becoming inexpensive compared to coal and natural gas [41]. Under these circumstances, it is becoming essential to explore and estimate the RE employment opportunities of various decarbonization pathways and RE goals underneath the NDCs.

Transformative approach influenced the labour market and reshaped globally the sectors including movement towards climate trade, digitalization and globalization [43–45]. Energy transformation had an important role towards societies and economic challenges globally. Furthermore, the COVID-19 crisis is certain to exacerbate inequality, both inside and across nations [46, 47]. Crises of COVID-19 require new approaches towards these challenges and require immediate response from policy makers and private energy sectors investments [43].

The renewable power sector has hired 12 million people in 2020 [48]. Employment has grown continuously globally in solar PV, bioenergy, hydropower, and wind strength industries had been the most important employers. According to IRENA's 2021, renewable energy employment globally [49] is estimated as shown in Figure 1.15. There are many factors affecting the employment trends. These factors include the speed at which renewable energy equipment are manufactured, installed and are used [49], as shown in Figure 1.16. Costs of solar and wind are reducing gradually, with proper investment moving towards larger job placements. Further investment in RE enhances new job opportunities and growing labour production.

Policy advisers and aid remain indispensable for setting up universal renewable energy roadmaps, riding ambition and encouraging the adoption of crystal-clear steady policies for feed-in tariffs, auctions, tax incentives, subsidies, permitting

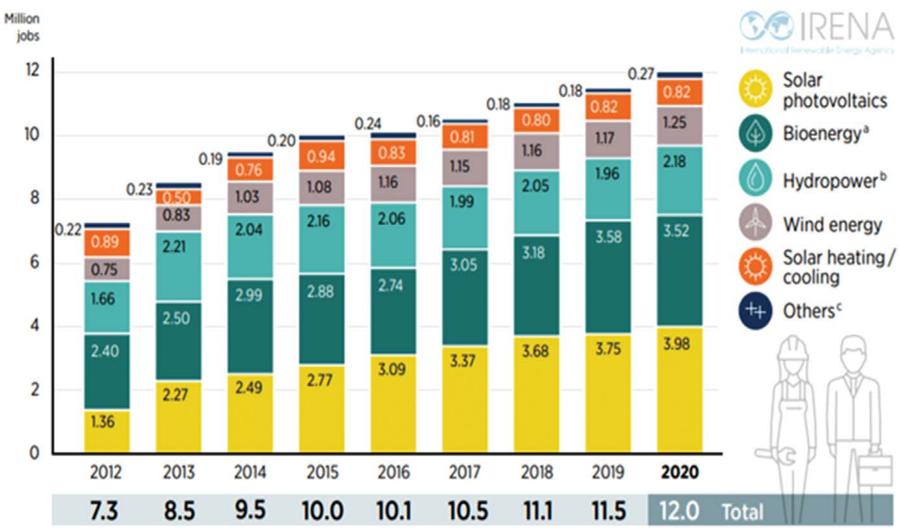

FIGURE 1.15 Global employment in renewable energy sector.

FIGURE 1.16 Factors influencing renewable energy employment [49].

techniques and other regulations [49]. The topographical footstep of renewable energy employment depends on technical policies, industrialized policies, skilful leader's consumer requirements and on the vigorousness of national and regional installation market, strength of production and distribution in the individual countries. Producing skilled team of engineers, scientists, project managers, technicians, electricians, welders, pipefitters, truck drivers, crane operators and many more are also necessary.

Figure 1.17 shows the continuous growth towards employment in RE sector and is expected to reach 42 million jobs by the end of 2050. The IEA has developed a sustainable recovery plan for generation and grid infrastructure energy efficiency buildings and industry sectors; manufacturing of vehicles and other transport measures as well as fuel production, renewables, recycling and innovation [50], as shown in Figure 1.18. Transition towards renewable energy will reduce jobs in fossil fuel sector while enhancing job in RE increasing over 15 million jobs worldwide by 2030 [50].

The planning and transformation energy scenario regarding jobs in energy sector is shown in Figure 1.19.

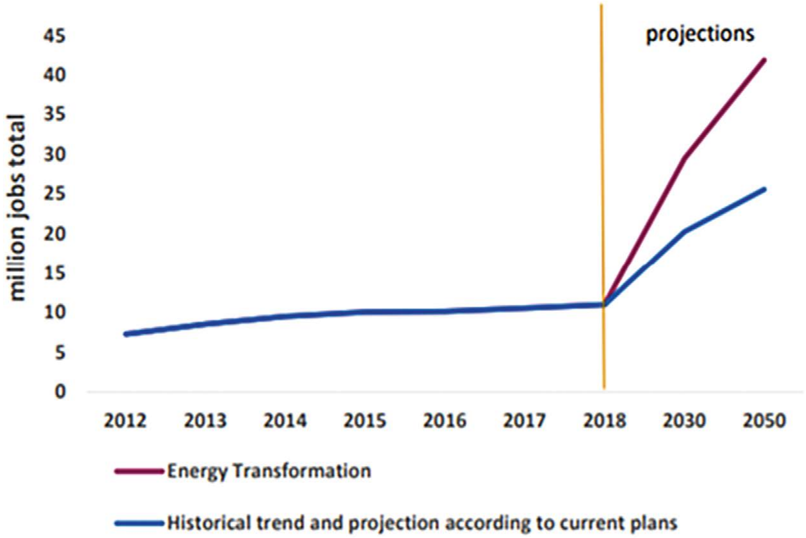

FIGURE 1.17 Global renewable energy employment estimated till 2018 and projected employments from 2030 to 2050.

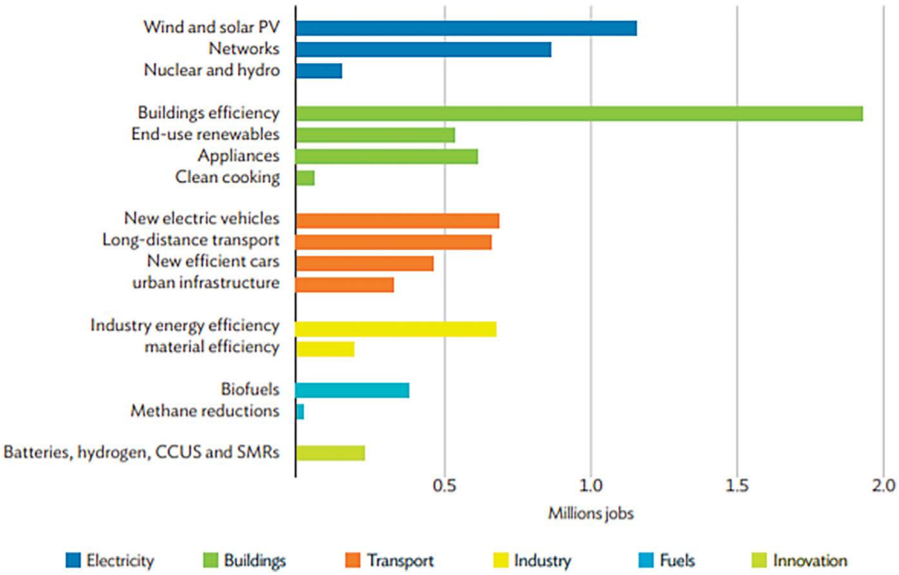

FIGURE 1.18 International Energy Agency's recovery plan of annual construction and manufacturing jobs [50].

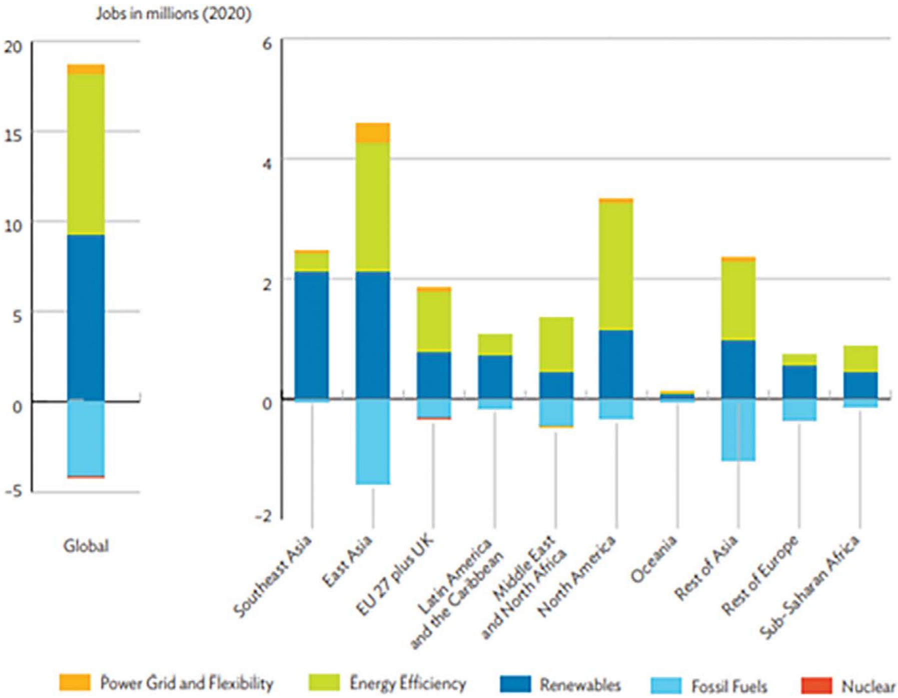

FIGURE 1.19 Jobs in energy sector in 2030 (planning and transforming energy scenario) [48].

1.8 IMPACT OF COVID-19 ON ENERGY

In the starting year of 2020, COVID-19 broke out at the international level leading to the death of many people and affecting the economy worldwide. Statistical analysis of COVID-19 was done by Johns Hopkins University on June 28, 2021 and declared 181,102,393 people infected and 3,923,132 people passed away globally [45]. Three countries namely the United States, India and Brazil had largest number of infected people and deaths globally. In order to stop the spreading of the virus, many countries made restrictions. Educational institutes were closed, partial or full lockdowns and work from residence was advised. These restrictions affected transportation, catering, entertainment, medical care, manufacturing, actual property and many other components. It is easy to portray that the foundation of the global economic system is shattered for most of 2020 and 2021 [49–50]. Worldwide population and energy sectors are the biggest sufferers during the COVID-19 pandemic.

Employment, together with inside the power sector, has been deeply affected by repeated lockdowns and different restrictions which placed stress on deliver chains and constrained financial activity. Many scholars and researchers have studied and discussed the influence of COVID-19 pandemic on energy market related to energy

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