UNIT 14 MITIGATION STRATEGIES

Structure

14.1 INTRODUCTION

The United Nations General Assembly adopted an important resolution (Res. 70) in September 2015 to set out 17 global Sustainable Development Goals (SDGs) and 169 targets to underpin transformation agenda popularly known as Post 2015 development agenda. Goal number 13 of this agenda calls upon to "take urgent action to combat climate change and its impacts". Another major development around the same time was the adoption of the Paris Agreement on Climate Change, in December 2015. Both of these developments strongly advocate for a global economy based on low-emissions pathways.

The third assessment report of IPCC conclusively established the fact that human activities were the dominant reason for global warming observed during past 50 years. Report further says that human activities will continue to change atmospheric composition during 21st century. Fossil fuel burning will be the major contributor for such adverse consequences of human activities. In all likely possibilities, use of coal will increase primarily because it is cheap and available in abundance in United States, China and India. Moreover, it can provide usable energy at a relatively more affordable cost between $1 and $2 per MMBtu as compared to $6 to $12 per MMBtu for oil and natural gas (MIT, 2007). We have well documented studies to convincingly believe that there is more carbon dioxide in our atmosphere than at any time in the past 400000 years. The levels of CO_2 have exceeded dangerous proportion of about 400 parts per million. The rate of growth of CO_2 emission has unprecedented implications for rise in global mean temperature. Even if the carbon reduction targets set out in the 2016 Paris Agreement can be met, global temperatures could rise above 1.5˚C by 2030 (Neil , 2019). In this unit, we would be discussing the climate change mitigation strategies. Further, we will be discussing the alternate energy options, carbon capture and sequestration and sustainable buildings.

14.2 OBJECTIVES

After studying this unit, you should be able to:

- define the climate change mitigation;
- discuss the mitigation strategies;
- explain carbon capture and sequestration;
- discuss the alternate energy options; and
- explain sustainable buildings.

14.3 CLIMATE CHANGE MITIGATION

The efforts made to prevent or reduce the release of greenhouse gas (GHG) emissions into the atmosphere or to enhance the absorption of GHGs already emitted, are referred as climate change mitigation. The primary aim of mitigation efforts is to reduce the magnitude of future warming. The measures used for climate change mitigation are mainly deployment of renewable energies and new technologies, enhancing energy efficiency, and improved sustainable agricultural and consumer practices (IPCC 2014; IPCC 2018). Intergovernmental Panel on Climate Change (IPCC 2014), defines mitigation as follows:

"The effort to control the human sources of climate change and their cumulative impacts, notably the emission of GHGs and other pollutants, such as black carbon particles, that also affect the planet's energy balance. Mitigation also includes efforts to enhance the processes that remove GHGs from the atmosphere, known as sinks" (IPCC, 2014).

Climate intervention measures consist of two major categories which are solar radiation management (SRM) and deployment of carbon dioxide removal (CDR) techniques (Royal Society 2009; IPCC 2018). The SRM measures primarily focus on the efforts to temporarily reduce or offset warming through changing the albedo. Such measures try to modify the earth's ability to reflect solar radiation which brings down the peak temperature from climate change. Another set of strategies aim at reducing the concentration of carbon dioxide or GHGs already in the atmosphere. CDR techniques are different from climate mitigation strategies as they do not focus on reducing the amount of carbon dioxide or GHG emissions entering the atmosphere (mitigation).

14.4 NEED TO STABILIZE GHG CONCENTRATIONS

CO_2 is the most important GHG from the point of view of global warming. Its major sources are burning of fossil fuels (for example coal, natural gas, and oil), solid waste, trees, and wood products and also certain chemical reactions (e.g., manufacture of cement or glass). Plants are the natural sink for the CO_2. The carbon dioxide injected in the atmosphere automatically gets recycled through carbon cycle. However, it has very high residence time in the atmosphere almost of the order of centuries. It means that its presence in the atmosphere continues to affect the wellbeing of people for decades and centuries. The continuous injection of CO_2 in the atmosphere obviously leads to more and more heat getting trapped in the atmosphere thereby leading to increased global average surface temperature. The increasing concentrations of several other GHGs (CH_4, N_2O, HFCs, PFCs, SF_6) are exacerbating the problem.

Climate system has a delayed response to the stock of GHG and equilibrium temperature grows linearly with cumulative emissions of CO_2 (Bosetti et al. 2014). The CO_2 concentration in the atmosphere, way back in 1972 was building up at the rate of around one part per million (ppm) per year (Sachs 2015) whereas now it is increasing steadily at about 2 ppm per year. According to the IPCC (2014),

"Mitigation scenarios in which it is likely that the temperature change caused by anthropogenic GHG emissions can be kept to less than 2 Degree Celsius relative to preindustrial levels are characterized by atmospheric concentrations in 2100 of about 450 ppm CO_2eq (equivalent)" (IPCC, 2014).

Therefore, CO_2 concentrations can be stabilized only if global emissions peak further decline to zero in the long term. Moreover, if we want to stabilize the CO_2 concentrations at a lower value then the peak should be sooner and lower. Further the stabilization of GHG concentrations calls for fundamental changes in the global energy system relative to a baseline scenario. For example, in order to bring CO_2eq concentrations of 450 ppm in 2100, CO_2 emissions from the energy supply sector should be brought down to 90% below 2010 levels between 2040 and 2070, and in many scenarios fall below zero thereafter. Such decline is possible keeping in view of consistent energy efficiency improvements and increasing share of low and zero carbon energy technologies and of technologies aimed at negative emissions. It is estimated that to preserve a 50% chance of limiting global warming to 2 degrees Celsius, the world has a carbon budget of 3000 gigatonnes (Gt) (IPCC 2014). However, an estimated 1,970 Gt had already been emitted before 2014 leaving the energy sector for rest of the twenty-first century a carbon budget of just 980 Gt (IEA 2015).

Check Your Progress 1

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) What are the SDG targets that have explicit linkages with climate change mitigation?

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14.5 MITIGATION STRATEGIES

One of the key responses to global warming has been to decrease the amount of GHG emissions released into the atmosphere by enhancing sinks. One of the major carbon sinks which you might be well familiar is the land cover of forests. Some mitigation strategies can be as follows:

- To develop and implement programs aimed at mitigating climate change.
- To initiate mitigation actions involving policies,
- To incentivize programs for clean activities across all sectors and involving all types of actors,
- To take initiatives and investment programs covering all sectors.
- To initiate mitigation actions such as increased use of renewable energy, application of new technologies in areas like lighting and transportation, and behavioral adjustments like lifestyle change.
- To conserve natural sinks through expanding forests
- To protect oceans, so that they remove more carbon dioxide from the atmosphere (UNFCCC)

There have been strong realizations that existing mitigation efforts fall short of the Paris Agreement's temperature targets (UNFCCC 2016; IPCC 2018). As per the synthesis report on the aggregate effect of 161 intended nationally determined contributions (INDCs) the impact of such NDCs is likely to lead to a 3 degree rise in temperature. It is much higher than 2- degree target and 1.5-degree aspirational target of Paris Climate Change Agreement (UNFCC, 2016).

It has triggered an idea of "...deliberate large-scale intervention in the Earth's climate system, in order to moderate global warming" (Royal Society 2009; IPCC 2018). There are two main overarching categories of climate intervention actions, first is Greenhouse Gas (GHG) removal and another is Solar Radiation Management (SRM) (Royal Society 2009). Among both of these strategies, Carbon dioxide removal (CDR) which primarily aims at removing atmospheric carbon is the most developed form of GHG removal. It includes ocean fertilization, ocean liming and carbon capture and storage. On the other hand, SRM techniques aims at intercepting solar radiation before it reaches Earth's surface for example through injecting particles into the stratosphere to deflect sunlight or spraying aerosols into low-lying marine clouds to make them more reflective (Royal Society 2009). However, climate intervention measures are complex and have raised several apprehensions that could have negative ecological and socio-economic effects (Encyclopedia, 2020). Moreover, the science of such climate intervention methods remains uncertain.

14.6 CARBON CAPTURE AND SEQUESTRATION (CCS)

CCS is a set of technologies that can greatly reduce carbon emissions from new and existing coal- and gas-fired power plants and large industrial sources. It is a three-step process which includes capture of carbon dioxide from power plants or industrial processes, its transport (usually in pipelines) to a site where it is injected underground for permanent storage (also known as "sequestration") into rock formations beneath the surface. The reductions of net CO_2 emissions provide a protection strategy for power plants that would otherwise be decommissioned or become stranded. Though a variety of pilot projects have critically advanced our understanding of the carbon capture technology, it is yet to be applied at large scale. There are still diverse opinions about its usefulness. One of the major reasons is that it is an expensive technology and therefore requires substantial cost reduction or economic incentives to become a dependable mechanism for large-scale future deployment of CCS. In addition to economic incentives, there is a strong need for well-framed regulation and coherent emission reduction policy scenarios. Moreover, there are apprehensions about long term safety and environmental concerns. Also, there is limited evidence of the potential consequences of a pressure buildup within a geologic formation caused by CO_2 storage (such as induced seismicity) and on the potential human health impacts from CO_2 that migrates out of the primary injection zone (IPCC 2014).

The ultimate objective of UNFCCC is to stabilize the GHG concentrations to prevent such anthropogenic changes in climate system from reaching dangerous levels. However, the specific level limits of such GHG have not been conclusively agreed to. The technological options available to bring down the carbon emissions are as follows: Reducing energy consumption through less energy-intensive economic activities and energy efficient processes; encouraging less carbon intensive fuels, increasing the use of renewable energy sources or nuclear energy, sequestering CO_2 by enhancing biological absorption capacity in forests and soils and lastly capturing and storing CO_2 chemically or physically (IPCC, 2005).

Though the first four options given above are already well documented in several other earlier IPCC reports, the fifth option i.e., carbon capture and storage were the subject matter of third IPCC report (IPCC, 2005). It propagated the idea that CO_2 produced by fossil fuel burning should be captured and stored away from the atmosphere for a very long period of time. The third assessment report examined the available knowledge about different dimensions of this option to explore whether it is viable option for mitigating climate change.

CASE STUDY-1: CARBON ENGINEERING

Carbon capture is increasingly been recognized as an important contributor to carbon mitigation efforts around the world. There are around 21 CCS projects in operation or under construction around the world. Various financial agencies and companies have started investing in this technology. One such venture is Carbon Engineering which has been capturing atmospheric carbon di-oxide since 2015, by constructing an end-to-end Direct Air Capture pilot plant in Squamish, B.C., Canada. This company was started in 2009 by a Harvard Professor David Keith, in Calgary, Alberta. A large team of academic scientists, business leaders, and strategic investors was involved and the main aim was to develop and commercialize technology that captures climate-relevant quantities of CO_2 from the air. In collaboration with Oxy Low Carbon Ventures, LLC (OLCV), a subsidiary of Occidental, this company is now working on the world's largest direct air capture plant that is one million tons of CO_2 directly from the atmosphere each year. The captured carbon di-oxide will be permanently stored underground. The carbon di-oxide will be utilized in OLCV's enhanced oil recovery operations. In 2021, CE is expected to start the construction of its first large-scale commercial plants. This project will be deployed in partnership with Oxy Low Carbon Ventures and will be built in the Permian Basin, U.S. Carbon Engineering is also progressing the opportunities to further Direct air capture plants in different markets around the world. In 2017, CE incorporated fuel synthesis capability into Direct air capture pilot plant of Squamish, making the world's first Air to Fuel pilot based on industrially scalable technologies.

Source: https://carbonengineering.com/our-story/

CASE STUDY-2: THE CARBFIX METHOD

Though carbon capture can be a vital option for any carbon reduction plan, there are several unanswered questions in this regard. For example, an important issue is what to do with the captured stuff. A possible solution is to bury the captured carbon dioxide, for example Reykjavik Energy's CarbFix Project in Iceland, since 2012, has been injecting carbon dioxide in water deep underground. The Carbfix method is considered to be an economical and environmentally friendly way to permanently immobilize carbon. It involves the process of dissolving CO_2 in water under pressure and then pumping it to a depth of 500-800 meters into basalt strata where it gets permanently mineralized. Reykjavik Energy (RE), since 2007 developed this method in collaboration with the University of Iceland and several other research institutions. Efforts have also been made to recycle captured carbon dioxide back into usable fuels such as ethanol under laboratory conditions, though it is yet to be commercialized.

14.7 ENERGY MANAGEMENT

Industrial development and population growth led to increased demand for energy during 1850-1970 primarily due to enormous increase in world population (~3.2 times), per capita use of industrial energy (~twenty-fold) and total world use of industrial and traditional energy (~ twelve-fold). This demand was predominantly met through biomass-based energy systems initially and gradually developed a heavy reliance on coal and gas. However, consumption of such non-renewable sources started generating high concentration of harmful gases in the atmosphere leading to serious repercussions like ozone depletion, higher levels of Greenhouse Gases (GHGs) and consequently the increasing global warming. The maximum contribution to GHG emissions comes from energy sector which roughly constitutes two third of all the anthropogenic GHG. The increasing dependence on fossil fuels is primarily driven by the electrification of the energy system (IPCC 2014). Therefore, electricity generation is the major sector which is responsible for emission of fossil fuel CO_2.

For a sustained economic growth, we need efficient, reliable and competitively priced energy supplies. This is the reason why efficient use and long-term sustainability of energy resources is at the core of energy management particularly in developing countries where the access to clean and reliable sources of energy is still a major challenge. There is a need to carefully plan the mitigation strategies both in the energy supply sector and energy demand sector. Energy supply sector includes all those processes that deliver final energy to the end-use sectors. However, the technological advancements have given rise to several mitigation options. Several possibilities exist in energy supply and demands sectors to mitigate the climate change, for example use of renewable and nuclear energy sources increased efficiency, fuel switching (e.g., from coal to gas), Carbon Capture and Sequestration (CCS), and energy efficiency at household or business level, or in transport.

14.7.1 Need for Energy Management

The fossil fuels have a limited stock in our environment. However, they are being consumed at very high rate. About 85 % of the primary energy at present comes from fossil fuels. Once they are completely consumed, we will not have such fuels available any more for future generations. Further we know that a significant amount of energy gets wasted in our country. There is a dire need to judiciously utilize energy resources and prevent energy death for our coming generation. For this purpose, we should have a proper understanding of how long such resources might be available and how they can be made to last longer. In this context the energy conservation and its management become an important issue of concern for all of us. How we produce and consume energy resources is a major issue of concern. In this regard the overall efficiency of energy production needs to take very seriously. Unfortunately, the overall energy efficiency is extremely low.

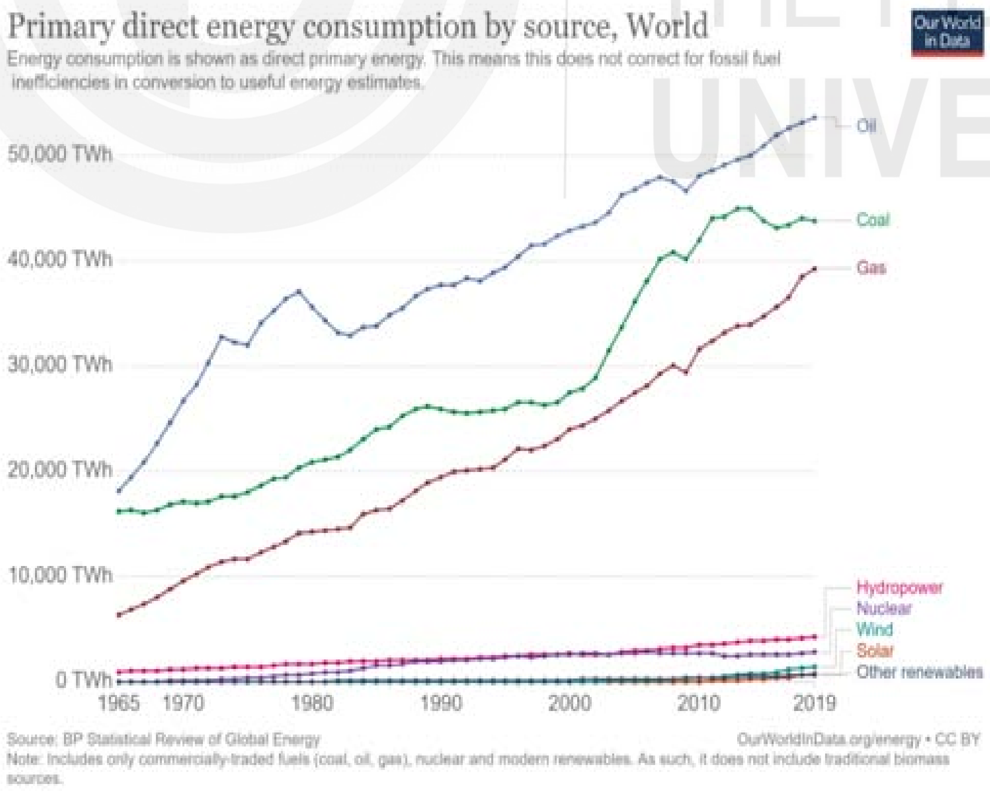

Fig. 14.1: Primary direct energy consumption by source, World

14.7.2 Energy Efficiency

Energy efficiency signifies using less energy for carrying out the same tasks. The energy efficiency carries significance because reduced energy consumption can bring down greenhouse gas emission. The concept of energy efficiency applies in several different areas for example designing of buildings, using smart meters or designing household appliances. As you know that compact fluorescent bulb uses less electricity than conventional electric bulb. Similarly internal temperature, illumination, landscaping etc. can be regulated through design considerations of the buildings to minimize energy consumption. Smart meters help to keep track of the usage of energy in the buildings to develop systems for making buildings more energy efficient. Such energy efficient design considerations in appliances, buildings etc. will help to consume lesser and lesser electricity and thus effectively contribute for climate change mitigation efforts. Here you need to understand the difference between energy conservation and energy efficiency. Though both of them have similar goal to reduce energy consumption, they are conceptually not the same. When we are talking about energy conservation, we are concerned about cutting back activities which consume energies, for example by switching off lights, driving less frequently, using appliances less etc. However, energy efficiency deals with our concern to harness technology to reduce energy wastage. Though development of such energy efficient devices or systems often cost intensive but the invested capital will pay back in long term through reduced energy consumption. Thus, improvement in energy efficiency is important in several ways. It is good for country's economy which would otherwise burden with energy import requirements, for people's domestic budget and most importantly for climate change mitigation besides the several indirect benefits like reduction in air and water pollution caused by unclean energy sources. Though renewable energy options can also help to address such issues, improvement in energy efficiency is the cheapest and most immediate way to reduce the carbon emissions.

Check Your Progress 2

Note: i) Use the space given below for your answers.

ii) Check your answers with those given at the end of the unit.

1) Differentiate between primary and secondary energy resources.

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2) Differentiate between renewable and non-renewable energy resources.

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3) Differentiate between commercial and non-commercial energy resources.

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14.8 ALTERNATE ENERGY OPTIONS

Due to the environmental problems created by the extensive use of fossil fuels, alternative sources of energy are being sought across the world. The ideal energy sources are the ones which last forever and do not pollute the environment. The energy sources derived from sun, wind, water, agricultural residues, fuel wood, and animal dung are inexhaustible and therefore popularly known as renewable sources. They are non-polluting and are available locally which is why they are viable sources of clean and limitless energy.

Among all the climate mitigation options, Renewable Energy (RE) is one of the most important options. The technologies powered by RE sources are much clean than those powered by fossil fuel-based resources. It is primarily because of the fact that lifecycle GHG emissions normalized per unit of electrical output (g CO_2eq/kWh) in such technologies is less (IPCC 2012). Despite their low life cycle GHG emissions, the long-term contribution for climate change mitigation in respect of few RE sources is limited. For example, for bioenergy, the available technical potential is limited, if we seek deep reductions in GHG emissions. However solar and wind energy, despite their seemingly higher technical potential for solar and wind energy, face obvious constraints due to changing weather patterns. The deployment of RE technologies is a complex matter which inter alia needs to take in to account environmental concerns, public acceptance, and investment in infrastructure.

14.8.1 Bioenergy

The energy produced from natural biological sources (e.g., plants, animals and their byproducts) is called bio-energy. It can be used in various forms like liquid form (e.g., biofuel), gaseous form (e.g., biogas) or solid form (e.g., burning wood for energy). Forests, agricultural fields and wastes are the prominent sources for the production of bioenergy. The raw materials derived from these sources can be converted in to bioenergy through chemical, thermal and biochemical methods. Under chemical processing biofuel is developed through chemical processes. In thermal conversion heat is used through combustion or gasification. In biochemical conversion processes, bacteria or other organisms are utilized to compost or ferment the source to convert it in to energy.

The energy retrieved from sources like plants is basically the solar energy stored in them through photosynthesis. Therefore, this source of energy can be replenished. The bioenergy can therefore be treated as inexhaustible source of energy. As the biomass is obtained from the farms, forests and other ecosystems, it has several positive and negative environmental and social impacts. Though it uses almost similar amount of carbon dioxide, as fossil fuels, we can minimize the adverse impact of such emissions by way of replacement of used resources by fast growing trees and plants (bioenergy feedstocks). However, through advanced technologies, bioenergy can reduce GHG emissions. Bioenergy can be generated locally at several levels for example individuals using compost heaps out of kitchen scraps or large-scale corporations using huge farms. Bioenergy has promising role to minimize GHGs and fulfill the energy needs of people beyond the reach of grid-based energy infrastructure. However, this form of energy generation is not yet fully ready to replace fossil fuels. It is too costly and utilize so many resources like large plots of land, water requirements etc., which make it unreasonable sometimes.

14.8.2 Solar Energy

As far as electricity generation is concerned, the solar energy technologies can be divided into two considerably different categories i.e., solar photovoltaic (PV) which transform sunlight in to electricity directly and concentrated solar power (CSP) which does it through the production of steam and the use of turbines and generators. These two technologies have another difference in that with CSP the storage is possible where as in case of PV, the storage is difficult and most expensive. The energy is abundantly available from the sun though it undergoes changes during night time or cloudy or rainy days. This is the reason why PV solar power systems need a backup system to maintain continuity in the energy supply. However, CSP technology requires much larger area and therefore suits the requirements in certain geographical areas and long days of direct sunlight. On the other hand, PV systems are scalable and therefore adaptable to different conditions. Though existing supply of solar energy is a small fraction of global energy supply, it has highest potential among all energy sources. As the technological advancements and cost reductions are continuously going on, we can hope to see a dramatic deployment of solar based technologies in near future.

14.8.3 Wind Energy

Wind energy is basically a kind of solar energy. It is created due to uneven warming of earth's atmosphere, differences in landscape and revolution of earth. Wind induced mechanical power is transmitted to generators which produce electricity. Wind energy is second fastest growing source of electricity in the world after solar energy, both of which are hygienic and cheapest option in many countries. China, USA and Germany are the prominent user countries of wind energy. However potential of wind energy generation depends upon region and season. Wind energy has a significant potential to address near term (2020) and long term (2030 to 2050) GHG emission reduction. The global wind energy capacity in 2017 had reached about 23 % of the global RE capacity largely from onshore wind applications (IRENA, 2018). Though there are range of wind energy technologies presently available in the market, there are environmental and social acceptability issues which restrict its possible use. Moreover, wind power cannot work when wind is not blowing and therefore cannot completely replace conventional sources. However, we can still rely on wind energies because they can put the polluting and inflexible power plants offline while they are in use and thus bring down GHG emissions.

14.8.4 Geothermal Energy

The heat (thermal) energy extracted from the interior of earth (geo) is known as geothermal energy. It resides within earth's interior in rocks, steam, or liquid water (filled in the fractures and pores within the rock). Geothermal energy is considered to be useful to generate utility scale electricity. In order to carry out this process deep wells are drilled to tap vapor and hot water from underground reservoirs. The steam is used to drive turbines to generate electricity.

Geothermal energy can also be used to heat and cool buildings. In many areas, during colder months the underground temperature remains constant (about 50–60°F) which is much warmer than the outside air. For the purpose of heating and cooling buildings, earth's surface is used as temperature exchange medium. It is achieved through geothermal (or ground-source) heat pumps.The heat can be absorbed through, water or another fluid running through pipes buried 10–300 feet underground or underwater. Subsequently deposited heat is passed through air ducts in the building. The cooling process is just the opposite. As opposed to fossil fuels geothermal energy does not discharge the GHGs. Moreover, the marginal cost of the fuel is low as the only cost involved in this process is the initial cost of set up. Keeping in view of its technical potential and likely deployment, it can meet about 3% of global demand for electricity by 2050. As on 2017, the capacity of geothermal energy is only 12,894 MW (IRENA 2018).

14.8.5 Hydroelectric Energy

The hydroelectric power is a mature technology though already over exploited in many regions. Hydropower is renewable because water is naturally replenished through the water cycle. Moreover, it is clean energy alternative because it does not add to the GHG emissions. Hydropower has the largest share of the global RE capacity though expected to decrease by 2050 (IRENA 2018). However, it continues to remain an attractive source keeping in view of global carbon mitigation scenarios. Hydroelectric projects are vulnerable to climate change effects primarily because of shifts in rainfall patterns.

14.8.6 Ocean Energy

The source of ocean energy is the kinetic, thermal, and chemical energy of seawater. This energy can be converted in to electricity and thermal energy. The oceans cover about 70% of earth's surface which make it the biggest collector of solar energy. The oceanic surfaces are warmed a lot more than deep oceanic water which creates thermal energy. Different kinds of technologies are used to convert different possible sources of ocean energy (e.g., waves, ocean currents, and tides). However, ocean energy's contribution for climate change mitigation is very less which is evident from the fact that -as on 2017- global capacity for ocean energy was just 529 MW (IRENA 2018). A better utilization of ocean resources will require improvement in various technologies and making it commercially viable at attractive rates.

14.8.7 Nuclear Energy

Nuclear energy is a matured technology which represented 11 % of the world's energy generation in 2012 with a total generation of 2346 TWh (IAEA 2013). It has low carbon emissions which is below 100 g CO_2eq per kWh on a lifecycle basis. Though globally it is utilized in 30 countries for electricity generation, a variety of safety concerns and nuclear waste management related issues have restricted its social acceptability. The nuclear accidents in 1986 at Chernobyl Ukraine and in 2011 at Fukushima Japan have created further apprehensions for safe utilization of nuclear energy. Since 1993 nuclear energy share of global electricity generation has been declining (IPCC 2014).

14.9 SUSTAINABLE BUILDINGS

The modern buildings require energies for a variety of purposes for example lighting, heating and cooling which is primarily met by commercial sources of energy. A significant part of the commercial energy is consumed by the buildings if it is not scientifically designed from the point of view of energy consumption. Such energy consumption takes place at several steps for example materials used in construction, developing comfortable living conditions inside the constructed building etc. As a result of fast expansion in construction sector, the requirement for energy consumption in this sector is increasing at a rapid pace. Keeping in view of the huge gaps in demand and supply of the commercial energy, there is a need to suitably design buildings. The architects, engineers, interior designers and other building design professionals have to play a significant role in this regard. The consumption of commercial energy can be significantly reduced by employing solar features in the building which are commonly called solar passive buildings or energy-conscious buildings. Energy savings result primarily due to reduction in energy used for thermal comfort conditioning and lighting when the building begins operation. On the other hand, solar active buildings use mechanical devices like pumps and fans etc., to distribute sun's captured energy amongst the areas of living spaces. The reduced consumption of commercial energy resources leads to reduction of greenhouse gases.

14.9.1 Designing Energy Efficient Buildings

Designing of energy efficient buildings requires several factors to be taken in to consideration. Some of these factors are size, shape, orientation, special arrangements, materials and many other factors that affect energy use with the building. The design of the building should be climate responsive to make them energy efficient and to reduce their energy consumption. Efforts should be made to integrate the buildings with renewable energy devices to generate energy at the site of building which will further reduce consumption of conventional energy sources. The building interacts with its environment through its walls, windows, roof, door and floor etc., which forms the building envelope. The energy efficiency of the building will obviously depend upon how well building envelop has been designed keeping in view of elements of climatic conditions such as solar radiation, ambient temperature, wind direction, level of humidity. For instance, we need to prevent heat gain and promote heat losses while constructing buildings in climatic zones represented as hot and dry, warm and humid, and moderate. However, in cold climatic zones, we need to promote heat gain and reduce the heat losses. Moreover, the site conditions (e.g., availability of trees, water bodies etc.), orientation of the building (which decides solar energy it receives during winters and summers) and proper building configuration also play a significant role in building's performance. The Government of India is promoting the solar buildings. The concept of such building is very close to architecture of heritage buildings viz. Red Fort of Delhi, forts and havelis in Jaipur, Jaisalmer and Jodhpur. Such architecture works in harmony of nature. The design of solar buildings helps to save money in long term through energy reduction though it may cost a little higher initially.

Check Your Progress 3

Note: i) Use the space given below for your answers.

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1) What are the advantages and disadvantages of Solar Passive Housing?

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14.10 LET US SUM UP

Keeping in view of the targets of Paris Agreement on climate change we can no longer emit any further carbon dioxide in the atmosphere. Therefore, reducing emissions of GHGs is one of the major challenges of our times. Though there are several sources of anthropogenic GHGs, the energy sector represents about two-thirds of such emissions. Within energy sector, electricity generation is the major contributor of CO_2. It is due to this reason that we expect this sector to play a major role in mitigation scenarios. It calls for, fostering renewable energies and new technologies, making older systems more energy efficient and changing management practices and consumer behavior.

We need to explore innovative ways to remove significant CO_2 from the atmosphere. In addition to biological options (e.g., afforestation and bioenergy with CO_2 capture) direct carbon capture and sequestration (DACC) has emerged as a promising possibility though it is yet to gain sufficient ground. Under the existing circumstances no credible emission scenario appears to emerge under which global mean temperatures can peak and then decline by 2100.

14.11 KEY WORDS

Mitigation: A human intervention to reduce the sources or enhance the sinks of greenhouse gases.

Solar Radiation Management (SRM): Solar Radiation Management refers to the intentional modification of the Earth's shortwave radiative budget with the aim to reduce climate change according to a given metric (e.g., surface temperature, precipitation, regional impacts, etc.).

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14.13 ANSWERS TO CHECK YOUR PROGRESS

Check Your Progress 1

1) The interconnections between climate change mitigation and some of the sustainable development goals are evident. The following table describes some of those targets which are explicitly connected.

Sustainable Development Goal	Target which is explicitly interlinked to climate change mitigation
No Poverty	SDG1.5
No Hunger	SDG2.4
Clean water and sanitation	SDG6.4 SDG6.6
Affordable and clean energy	SDG7.1 SDG7.2 SDG7.3
Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation	SDG9.4

Sustainable cities and communities	SDG11.B
Responsible production and consumption	SDG12.2 SDG12.4
Climate action	SDG13.2 SDG13.3 SDG13A

Check Your Progress 2

1) The primary sources of energy are found in nature and they are then converted in to secondary sources through industrial operations. For example, coal, oil and gas are primary sources whereas steam and electricity are secondary sources of energy.

2) The resources like coal, oil and gas have limited stock on the earth. They get continuously depleted as it is not possible to recoup their stock within a reasonable period of time. These kinds of resources are called fossil fuels because they are found underground where they are formed over millions of years. Hence such resources have limited supplies and are practically non-renewable. However hydro energy, wind energy, biomass energy, solar energy, tidal and geo-thermal energy are dependent on sun and will continue to last till sun exists. This is the reason why we call them renewable, nonconventional or alternative energy sources.

3) Commercial energy resources are available in the market for a specific price for example coal, oil, natural gas, electricity and refined petroleum products. However, non-commercial energy resources are not bought or sold at any specific prices in markets for example, cattle dung, agricultural wastes, solar energy, animal power for transport.

Check Your Progress 3

1) Advantages of Solar Passive Systems

Solar passive systems are highly energy efficient as a result of which the energy requirements for lighting, winter heating, and summer cooling are reduced substantially. Since such systems have very little dependence on conventional sources of energy, it helps to save on expenditures and consumption of fossil fuels (coal, oil and gas). Further such systems reduce the emission of greenhouse gases.

Disadvantages of Solar Passive Systems

The solar passive systems costs little more than conventional building design therefore initial cost is on higher side. Moreover, the design of such buildings has to be carefully planned and any mistake, for example in the choice of building materials or window glass, may give adverse results.