UNIT I
RENEWABLE ENERGY (RE) SOURCES

Environmental consequences of fossil fuel use, Importance of renewable sources of energy, Sustainable Design and development, Types of RE sources, Limitations of RE sources, Present Indian and international energy scenario of conventional and RE sources.

Introduction

Renewable energy is energy produced from sources that do not deplete or can be replenished or refilled within a human's life time. The most common examples of renewable energy sources include wind, solar, geothermal, biomass, and hydropower. Non-renewable energy comes from sources that will run out or will not be replenished in our lifetime or even in many lifetimes. Most of the non-renewable energy sources are fossil fuels, which influence the environment greatly and contribute to harmful global warming and climate change. Renewable energy is sustainable as it originates from sources that are inexhaustible (unlike fossil fuels). Despite of many advantages renewable energy sources have certain limitations like higher capital cost, intermittency, storage capabilities, geographic limitations, etc., which make them inevitable.

Environmental consequences of fossil fuel use

Fossil fuels are formed from the fossilized, buried remains of plants and animals that lived millions of years ago so they are named accordingly. Fossil fuels, which include coal, natural gas, petroleum, shale oil, and bitumen, are the main sources of heat and electrical energy. All these fuels contain the major constituents like carbon, hydrogen, oxygen and other materials like metal, sulphur and nitrogen compounds. During the combustion process different pollutants like fly ash, sulphur oxides (SO_2 and SO_3), nitrogen oxides ($NO_x = NO_2 + NO$) and volatile organic compounds are emitted. Gross emission of these pollutants constitutes to atmospheric pollution and can affect human beings and environment.

TEDA is Tamil Nadu Energy Development Agency. It is an independent agency setup by Government of Tamil Nadu in the year 1984, as a registered society with a specific purpose – to create awareness and migrate the State from using fossil fuels to renewable energy.

Atmospheric Pollution

Atmospheric pollution occurs in many forms but can generally be thought of as gaseous and particulate contaminants that are present in the earth's atmosphere. Chemicals discharged into the air that have a direct impact on the environment are called primary pollutants. These primary pollutants sometimes react with other chemicals in the air to produce secondary pollutants. The most commonly found air pollutants are oxides of Sulphur, oxides of nitrogen, oxides of carbon, hydrocarbons, particulates (fly ash).

Oxides of Sulphur (SO2)

Sulphur dioxide (SO_2) is a colourless gas with a sharp, irritating odour. It is produced by burning fossil fuels and by the smelting of mineral ores that contain sulphur. Erupting volcanoes can be a significant natural source of sulphur dioxide emissions.

Environmental effects

When sulphur dioxide combines with water and air, it forms sulphuric acid, which is the main component of acid rain. Acid rain can:

- Cause deforestation
- Acidify waterways to the detriment of aquatic life
- Corrode building materials and paints.

Health effects

- Sulphur dioxide affects the respiratory system, particularly lung function and can irritate the eyes.
- Sulphur dioxide irritates the respiratory tract and increases the risk of tract infections.
- It causes coughing, mucus secretion and aggravates conditions such as asthma and chronic bronchitis.

Oxides of Nitrogen (NOx)

The term nitrogen oxides (NOx) describes a mixture of nitric oxide (NO) and nitrogen dioxide (NO_2), which are gases produced from natural sources, motor vehicles and other fuel burning processes. Nitric oxide is colourless and is oxidised in the atmosphere to form nitrogen dioxide. Nitrogen dioxide has an odour and is an acidic and highly corrosive gas that can affect our health and environment. In poorly ventilated situations, indoor domestic appliances such as gas stoves and gas or wood heaters can be significant sources of nitrogen oxides.

Environmental and health effects of nitrogen oxides

- Elevated levels of nitrogen dioxide can cause damage to the human respiratory tract and increase a person's vulnerability to respiratory infections and asthma.
- Long-term exposure to high levels of nitrogen dioxide can cause chronic lung disease.
- It may also affect the senses of smell an odour.
- High levels of nitrogen dioxide are also harmful to vegetation, damaging foliage, decreasing growth or reducing crop yields.
- Nitrogen dioxide can fade and discolour furnishings and fabrics, reduce visibility and react with surfaces.

Oxides of Carbon (CO, CO2)

Carbon monoxide is a colourless, odourless gas formed when substances containing carbon (such as petrol, gas, coal and wood) are burned with an insufficient supply of air. Motor vehicles are the main source of carbon monoxide pollution in urban areas.

Health effects

- Carbon monoxide has serious health impacts on humans and animals.
- When inhaled, the carbon monoxide bonds to the haemoglobin in the blood in place of oxygen to become carboxyhaemoglobin. This reduces the oxygen-carrying capacity of the red blood cells and decreases the supply of oxygen to tissues and organs, especially the heart and brain.
- For people with cardiovascular disease, this can be a serious problem.
- The effects are reversible, so symptoms decrease gradually when exposure to carbon monoxide stops.

Hydrocarbons

A hydrocarbon is any compound that consists of carbon and hydrogen atoms. They are organic compounds. Because of the unique covalent nature of carbon, there are thousands upon thousands of hydrocarbons in the world. Gasoline, petroleum, coal, kerosene, charcoal, natural gas, etc., are all a form of hydrocarbons.

Environmental and health effects of hydrocarbons

- These substances contribute to the greenhouse effect and climate change
- Deplete the ozone
- Reduce photosynthetic ability of plants
- Increase occurrences of cancer and respiratory disorders in humans.

India uses about 500 million T of coal every year to produce electricity, about 3.6 trillion cubic feet of natural gas for power, chemicals and fertilizers and over 160 million T of oil for transport and industry.

Particulates (Fly Ash)

Fly ash is composed of tiny, airborne particles and is thus considered as a type of particulate matter or particle pollution. Fly ash contains different trace elements (heavy metals).

Environmental and health effects of fly ash

Wet ash ponds can pollute groundwater and if ingested, the arsenic contaminated water increases a person's risk of developing cancer.

Inhalation or ingestion of the toxins in fly ash can have impacts on the nervous system, causing cognitive defects, developmental delays, and behavioural problems while also increasing a person's chance of developing lung disease, kidney disease, and gastrointestinal illness.

When ash is disposed in dry landfills or wet ponds, there are associated environmental effects. Wet surface impoundments account for a fifth of coal ash disposal. These wet impoundments can be an issue if they do not have proper liners for the landfill or pond to prevent leaking and leaching. Both leaking and leaching lead to groundwater contamination.

Leaching is a process that occurs when fly ash is wet, and it simply means that the toxic components of the ash dissolve out and percolate through water. This groundwater contamination can be harmful to human health if the groundwater is a source of drinking water. In addition to leaching, fly ash toxics are able to travel through the environment as a result of erosion, runoff, or through the air as fine dust. The fact that the chemicals in the ash can escape and move through the environment is what makes fly ash harmful

Green House Gas Emissions from Various Energy Sources

Greenhouse gases are gases in earth's atmosphere that trap heat. They let sunlight pass through the atmosphere, but they prevent the heat that the sunlight brings from leaving the atmosphere.

Most of the emissions of human-caused (anthropogenic) greenhouse gases come primarily from burning fossil fuels like coal, hydrocarbon gas liquids, natural gas and petroleum, for energy use. Global warming or climate change has been observed for around 150 years and is a growth in this phenomenon.

The other GHG that are emitted as a result of human activity are

- Methane (CH_4), which comes from landfills, coal mines, agriculture, and oil and natural gas operations
- Nitrous oxide (N_2O), which comes from using nitrogen fertilizers and certain industrial and waste management processes and burning fossil fuels
- High global warming potential (GWP) gases, which are human-made industrial gases
- Hydrofluorocarbons (HFCs)
- Perfluorocarbons (PFCs)
- Sulfur hexafluoride (SF_6)
- Nitrogen trifluoride (NF_3)

Importance of renewable sources of energy

Renewable energies are obtained from sources of clean, inexhaustible and increasingly competitive energy. They differ from fossil fuels principally in their diversity, abundance and potential for use anywhere on the planet. In addition, they produce neither greenhouse gases – which cause climate change – nor polluting emissions. Their costs are also falling at a sustainable rate, whereas the general cost trend for fossil fuels is in the opposite direction in spite of their present volatility.

Renewable energies received assistance from the international community through the Paris Accord signed at the World Climate Summit held in Paris on December 2015. The agreement, which will enter into force in 2020, establishes, for the first time in history, a binding global objective. Nearly 200 signatory countries pledged to reduce their emissions so that the average temperature of the planet at the end of the current century remains well below 2° C, the limit above which climate change will have more catastrophic effects. However the aim is to keep it to 1.5° C.

Of the total renewable energy capacity of about 32,730MW installed all over India, TN alone has about 8326.86MW, thus about 25.44% of the total installed capacity, with Tamil Nadu having about 34.31% of the total wind energy installed capacity in India.

Other importance of renewable energy are:

Indispensable partner in the fight against climate change: Renewables do not emit greenhouse gases in energy generation processes, making them the cleanest, most viable solution to prevent environmental degradation. Most renewable energy sources produce little to no global warming emissions. Even when

including “life cycle” emissions of clean energy (i.e, the emissions from each stage of manufacturing, installation, operation, decommissioning), the global warming emissions associated with renewable energy are minimal.

Inexhaustible: Compared to conventional energy sources such as coal, gas, oil and nuclear - reserves of which are finite - clean energies are just as available as the sun from which they originate and adapt to natural cycles, hence their name “renewables”. This makes them an essential element in a sustainable energy system that allows development today without risking that of future generations.

Reducing energy dependence: The indigenous nature of clean sources gives local economies an advantage and brings meaning to the term “energy independence”. Dependence on fossil fuel imports results in subordination to the economic and political short-term goals of the supplier country, which can compromise the security of energy supply.

Increasingly competitive: The main renewable technologies – such as wind and solar photovoltaic – are drastically reducing their costs, such that they are fully competitive with conventional sources in a growing number of locations. Economies of scale and innovation are already resulting in renewable energies becoming the most sustainable solution, not only environmentally but also economically, for powering the world. Renewable energy is providing affordable electricity across the country right now, and can help stabilize energy prices in the future.

Benefiting from a favourable political horizon: The international community has understood its obligation to firm up the transition towards a low-carbon economy in order to guarantee a sustainable future for the planet. International consensus in favour of the “de-carbonization” of the economy constitutes a very favourable framework for the promotion of clean energy technologies.

Improved public health: Wind, solar, and hydroelectric systems generate electricity with no associated air pollution emissions. Geothermal and biomass systems emit some air pollutants, though total air emissions are generally much lower than those of coal- and natural gas-fired power plants. In addition, wind and solar energy require essentially no water to operate and thus do not pollute water resources or strain supplies by competing with agriculture, drinking water, or other important water needs.

Jobs and other economic benefits: Compared with fossil fuel technologies, which are typically mechanized and capital intensive, the renewable energy industry is more labour intensive. Solar panels need humans to install them; wind farms need technicians for maintenance. This means that, on average, more jobs are created for each unit of electricity generated from renewable sources than from fossil fuels.

Reliability and resilience: Wind and solar are less prone to large-scale failure because they are distributed and modular. Distributed systems are spread out over a large geographical area, so a severe weather event in one location will not cut off power to an entire region. Modular systems are composed of numerous individual wind turbines or solar arrays. Even if some of the equipment in the system is damaged, the rest can typically continue to operate. Wind and solar photovoltaic systems do not require water to generate electricity and can operate reliably in conditions that may otherwise require closing a fossil fuel-powered plant due to water scarcity.

Sl. No	Renewable Energy	Advanatges
1	Solar energy (From the sun)	• Sunlight does not produce any wastes or pollutants for environment. • It is free to collect sunlight as it is always present
2	The Wind	• The wind does not produce any wastes or pollutants for environment. • It takes up little ground space
3	Hydropower	• Hydropower is considered as inexpensive source. • It does not leave any harmful chemicals as waste.
4	Biomass	• Growing biomass crops use up carbon dioxide and increase oxygen

		• Biomass is always available, thus, it can be used as renewable resource.
5	Geothermal Energy:	• For heating and cooling, geothermal heat pump systems use 25% to 50% less electricity than conventional systems. • Biomass is always available and can be used as a renewable resource

Sustainable Design and development

Sustainable energy is a form of energy that meet our today's demand of energy without putting them in danger of getting expired or depleted and can be used over and over again. Sustainable energy should be widely encouraged as it do not cause any harm to the environment and is available widely free of cost. All renewable energy sources like solar, wind, geothermal, hydropower and ocean energy are sustainable as they are stable and available in plenty.

Sustainable energy sources

Fossil fuels are not considered as sustainable energy sources because they are limited, cause immense pollution by releasing harmful gases and are not available everywhere on earth. There are many forms of sustainable energy sources that can be incorporated by countries to stop the use of fossil fuels. Sustainable energy does not include any sources that are derived from fossil fuels or waste products. This energy is replenishable and helps to reduce greenhouse gas emissions and causes no damage to the environment. Hydropower is the most common form of alternative energy used around the world.

Need for Sustainable Energy

During ancient times, wood, timber and waste products were the only major energy sources. In short, biomass was the only way to get energy. When more technology was developed, fossil fuels like coal, oil and natural gas were discovered. Fossil fuels proved boom to the mankind as they were widely available and could be harnessed easily. When these fossil fuels were started using extensively by all the countries across the globe, they led to degradation of environment. Coal and oil are two of the major sources that produce large amount of carbon dioxide in the air. This led to increase in global warming. Also, few countries have hold on these valuable products which led to the rise in prices of these fuels. Now, with rising prices, increasing air pollution and risk of getting expired soon, forced scientists to look out for some alternative or renewable energy sources. Sustainable Energy came into the picture as it could meet our today's increasing demand of energy and also provide us with an option to make use of them in future also.

Sustainable Design

Sustainable design seeks to reduce negative impacts on the environment and the health and comfort of human beings, thereby improving performance of energy systems. Sustainable design principles include the ability to:

- optimize site potential;
- minimize non-renewable energy consumption;
- use environmentally preferable products;
- protect and conserve water;
- enhance indoor environmental quality; and
- optimize operational and maintenance practices.

Utilizing a sustainable design philosophy encourages decisions at each phase of the design process that will reduce negative impacts on the environment and the health of mankind, without compromising the bottom line. It is an integrated, holistic approach that encourages compromise and trade-offs. Such an integrated approach positively impacts all phases of an energy source life-cycle, including design, construction, operation and decommissioning.

- *25068 Solar domestic lighting systems installed in Tamil Nadu with assistance from Government.*
- *6095 Solar street lights installed in pubic places/streets mostly in village panchayats with Government assistance and active support and involvement of Rural Development Department.*

Examples of sustainable green buildings in Chennai

Anna Centenary Library

The Anna Centenary Library is located at Kotturpuram, Chennai and has also been awarded the LEED (Leadership in Energy and Environmental Design) Gold rating. An artificial tree is established at the middle of the library to promote awareness about conservation of trees. Water is recycled by an on-plant treatment unit and subsequently uses 64% less water than any other building of the same size. Power conservation steps are also taken which translates to a saving of 17.5% than buildings of the same size.

Government Super Specialty Hospital

Govt. Super Specialty Hospital which is located at Triplicane contributes to the ever-growing list of Green Buildings in Chennai. The large building has adopted excellent eco-conservative methods and continues to be successful in preserving energy and water resources

World Bank

The World Bank is located at Tharamani and is a certified green building. The office has always strived hard to entwine environmental concern with development and operational strategy. The office boasts of water recycling plant, carbon sensors, automated lighting, etc., Also, the World Bank office at Chennai is its largest branch outside of Washington DC and encompasses a wide area of 1,28,000 square feet which showcases the steadfast dedication shown by the employees and the administrators to conserve natural resources.

Express Avenue

Located at Royapettah, Express Avenue is also recognized as a green building which further shows that builders are becoming conscious about the environment. The mall is covered with windows made up of an environmentally-conservative material or more specifically with tensile fabric. It also has an in-built sewage treatment plant and is worthy of a place in the top 10 green buildings list.

Raintree Hotel

The Raintree Hotel is considered to be one of the first Green Buildings of South India and has an eco-sensitive policy. The hotel has adopted a set of eco-friendly steps without compromising quality for the customers. Water for the air-conditioners is processed and recycled using a sewage treatment plant which helps preserve water resources. The heat generated by the air conditioners is used to heat the waters in the washroom. The employees working at the Raintree Hotel are also made to emphasize and adopt the eco-sensitive policy.

Solar Panels

In Brisbane Australia, the Kurilpa Bridge holds the title of the largest foot bridge powered by solar panels. Solar photovoltaic systems are the easiest and most common form of renewable energy within residential homes and now in public structures as well. The Kurilpa bridge save 37.8 tonnes of carbon emissions yearly as its LED lighting system is powered solely by the sun.

Wind Turbines

The Bahrain World Trade Centre is a revolutionary structure. It is the first commercial building to use wind turbines on a horizontal axis, attached to the actual building for electricity. The wind powers a generator resulting in electricity. The Bahrain World Trade Centre has just over 15% of its entire energy needs powered by the 675 kW (kilowatt) turbines.

Renewable energy and sustainable development

Renewable energy has a direct relationship with sustainable development through its impact on human development and economic productivity. Renewable energy sources provide opportunities in energy security, social and economic development, energy access, climate change mitigation and reduction of environmental and health impact.

Energy security

The notion of energy security is generally used, however there is no consensus on its precise interpretation. Yet, the concern in energy security is based on the idea that there is a continuous supply of

energy, which is critical for the running of an economy. Renewable energy sources are evenly distributed around the globe as compared to fossils and in general less traded on the market. Renewable energy reduces energy imports and contribute diversification of the portfolio of supply options and reduce an economy's vulnerability to price volatility and represent opportunities to enhance energy security across the globe. The introduction of renewable energy can also make contribution to increasing the reliability of energy services, to be specific in areas that often suffer from insufficient grid access. A diverse portfolio of energy sources together with good management and system design can help to enhance security.

Social and economic development

Generally, the energy sector has been perceived as a key to economic development with a strong correlation between economic growth and expansion of energy consumption. Globally, per capita incomes are positively correlated with per capita energy use and economic growth can be identified as the most essential factor behind increasing energy consumption in the last decades. It in turn creates employment; renewable energy study in 2008, proved that employment from renewable energy technologies was about 2.3 million jobs worldwide, which also has improved health, education, gender equality and environmental safety.

Energy access

The sustainable development seeks to ensure that energy is clean, affordable, available and accessible to all and this can be achieved with renewable energy source since they are generally distributed across the globe. Access concerns need to be understood in a local context and in most countries there is an obvious difference between electrification in the urban and rural areas, this is especially true in sub-Saharan Africa and South Asian region. Distributed grids based on the renewable energy are generally more competitive in rural areas with significant distances to the national grid and the low levels of rural electrification offer substantial openings for renewable energy-based mini-grid systems to provide them with electricity access.

Climate change mitigation and reduction of environmental and health impacts

Renewable energy sources used in energy generation helps to reduce greenhouse gases which mitigates climate change, reduce environmental and health complications associated with pollutants from fossil fuel sources of energy.

> *The Indian renewable energy is ranked fourth in wind power, fifth in solar power and fifth in renewable power installed capacity as of 2018. In 2019, India was ranked as the fourth most attractive renewable energy market in the world.*

Types of RE sources

Alternative or renewable energy comes from natural processes that can reliably produce cheap energy with minimal impact to the environment. The most popular renewable energy sources currently are:

- Solar energy
- Wind energy
- Hydro energy
- Tidal energy
- Geothermal energy
- Biomass energy
- Hydrogen

Solar energy

Sunlight is a renewable resource, and its most direct use is achieved by capturing the sun's energy. A variety of solar energy technologies are used to convert the sun's energy and light into heat: illumination, hot water, electricity and (paradoxically) cooling systems for businesses and industry.

Photovoltaic (PV) systems use solar cells to convert sunlight into electricity. Solar hot water systems can be used to heat buildings by circulating water through flat-plate solar collectors. Mirrored dishes that are focused to boil water in a conventional steam generator can produce electricity by concentrating the sun's heat. Commercial and industrial buildings can also leverage the sun's energy for larger-scale needs such as

ventilation, heating, and cooling. Finally, thoughtful architectural designs can passively take advantage of the sun as a source of light for heating and cooling.

Homeowners, businesses and government entities can take advantage of the benefits of solar power in many ways: Install a home solar system or commercial solar panels; construct or retrofit a building to incorporate solar hot water, cooling or ventilation systems; design from scratch structures that take advantage of the sun's natural attributes for passive heating and lighting.

Wind energy

Wind can be considered a form of solar energy because of the uneven heating and cooling of the atmosphere cause winds (as well as the rotation of the earth and other topographical factors). Wind flow can be captured by wind turbines and converted into electricity. On a smaller scale, windmills are still used today to pump water on farms.

Commercial grade wind-powered generating systems are available to meet the renewable energy needs of many organizations.

Single-wind turbines can generate electricity to supplement an existing electrical supply. When the wind blows, the power generated by the system goes to offset the need for utility-supplied electricity.

Utility-scale wind farms generate electricity that can be purchased on the wholesale power market, either contractually or through a competitive bid process.

Hydro energy

Hydropower is not a new invention, though the waterwheels once used to operate the gristmills and sawmills of early America are now largely functioning as historic sites and museums. Today, the kinetic energy of flowing rivers is captured in a much different way and converted into hydroelectricity. Probably the most familiar type of hydroelectric power is generated by a system where dams are constructed to store water in a reservoir which, when released, flows through turbines to produce electricity. This is known as "pumped-storage hydropower," where water is cycled between lower and upper reservoirs to control electricity generation between times of low and peak demand.

Another type, called "run-of-river hydropower," funnels a portion of river flow through a channel and does not require a dam. Hydropower plants can range in size from massive projects such as Hoover Dam to micro-hydroelectric power systems. The direct use of hydroelectric power is naturally dependent on geographic location. Assuming a dependable waterway source is accessible and available, micro-hydroelectric plants can be constructed to supply electricity to farm and ranch operations or small municipalities.

Ocean energy

There are two types of energy that can be produced by the ocean: thermal energy from the sun's heat and mechanical energy from the motion of tides and waves.

Ocean thermal energy can be converted into electricity using a few different systems that rely on warm surface water temperatures. "Ocean mechanical energy" harnesses the ebbs and flows of tides caused by the rotation of the earth and the gravitational influence of the moon. Energy from wind-driven waves can also be converted and used to help reduce one's electricity costs.

There are also lesser developed technologies that leverage ocean currents, ocean winds and salinity gradients as sources of power conversion.

Cold ocean water from deep below the surface can be used to cool buildings (with desalinated water often produced as a by-product), and seaside communities can employ the methods to tap natural ocean energy described above to supplement municipal power and energy needs.

Ocean energy is an evolving source of alternative energy production, and with more than 70 percent of the surface of our planet covered by ocean, its future looks promising, depending on geographies and regulatory guidelines.

Geothermal energy

Geothermal energy is derived from the heat of the earth. This heat can be sourced close to the surface or from heated rock and reservoirs of hot water miles beneath our feet. Geothermal power plants harness

these heat sources to generate electricity. On a much smaller scale, a geothermal heat pump system can leverage the constant temperature of the ground found just 10 feet under the surface to help supply heat to a nearby building in the winter or to help cool it in the summer.

Geothermal energy can be part of a commercial utility energy solution on a large scale or can be part of a sustainable practice on a local level. Direct use of geothermal energy may include Heating office buildings or manufacturing plants; helping to grow greenhouse plants; heating water at fish farms; and aiding with various industrial processes (e.g., pasteurizing milk).

Biomass energy

Bioenergy is a type of renewable energy derived from biomass to create heat and electricity or to produce liquid fuels such as ethanol and biodiesel used for transportation.

Biomass refers to any organic matter coming from recently living plants or animals. Even though bioenergy generates about the same amount of carbon dioxide as fossil fuels, the replacement plants are grown as biomass to remove an equal amount of CO_2 from the atmosphere, keeping the environmental impact relatively neutral.

There are a variety of systems used to generate this type of electricity, ranging from directly burning biomass to capturing and using methane gas produced by the natural decomposition of organic material.

Manufacturing facilities can be equipped to burn biomass directly to produce steam captured by a turbine to generate electricity. In some cases, this process can have a dual purpose by powering the facility as well as heating it. For example, paper mills can use wood waste to produce electricity and steam for heating. Farm operations can convert waste from livestock into electricity using small, modular systems. Towns can tap the methane gas created by the anaerobic digestion of organic waste in landfills and use it as fuel for generating electricity.

Hydrogen - High Energy/Low Pollution

Hydrogen is the simplest (comprised of one proton and one electron) and the most abundant element in the universe, yet it does not occur naturally as a gas on earth. Instead, it is found in organic compounds (hydrocarbons such as gasoline, natural gas, methanol, and propane) and water (H_2O). Hydrogen can also be produced under certain conditions by some algae and bacteria using sunlight as an energy source.

Hydrogen is high in energy yet produces little or no pollution when burned. Liquid hydrogen has been used to launch space shuttles and other rockets into orbit since the 1950s. Hydrogen fuel cells convert the potential chemical energy of hydrogen into electricity, with pure water and heat as the only by-products. However, the commercialization of these fuel cells as a practical source of green energy will likely be limited until costs come down and durability improves. Almost all the hydrogen used in the United States is used in industry to refine petroleum, treat metals, produce fertilizer and process foods. In addition, hydrogen fuel cells are used as an energy source where hydrogen and oxygen atoms are combined to generate electricity.

There are also currently a few hundred hydrogen-powered vehicles operating in the United States, a number that could increase as the cost of fuel cell production drops and the number of refuelling stations increases. Other practical applications for this type of renewable energy include large fuel cells providing emergency electricity for buildings and remote locations, electric motor vehicles powered by hydrogen fuel cells and marine vessels powered by hydrogen fuel cells.

Wind power accounted for the highest at 46% (around 36 GW), followed by solar with a share of 36% (30 GW). The remaining market was captured by biomass at 12% (9 GW) and small hydro projects catering to 6% (5 GW).

Limitations of RE sources

Despite of advantages when it comes to renewable energy, the positives outweigh the negatives. Some of the limitations of renewable energy sources are;

- Some type of renewable energy sources is location-based and commercially feasible
- These types of energies need storage capacities
- Some energy sources cause pollution.
- Renewable energies frequently need funding for making them reasonable

- Some types of energy sources require a huge space

Limitations of solar

1) **Higher Costs than Fossil Energy Forms** –It has been estimated that solar power costs fall by 20% for every 100% increase in supply. The Solar Cost Curve has declined massively in the last 2 years as cheap Chinese solar production has made solar panel costs come down by 50%. Note in the next 4-5 years expect an average decline of around 10% per year which would make solar energy competitive with fossil fuel energy in most parts of the world. Current solar power costs between 15-30/Kwh depending on the solar radiation of the particular location, type of technology used etc.
2) **Intermittent Nature** – One of the biggest problems of Solar Power is that it is intermittent in nature as it generates energy only when the sun shines. This problem can be solved with energy storage however this leads to additional costs. Smart Grids and Cheaper Energy Storage in the future should allow even higher penetrations of Wind and Solar Power possible.

3) **High Capital Investment** – A Solar Plant can cost around 450 lakhs to be spent in building 1 Megawatt. This is said to be too high, however the costs of energy can only be compared by Levelized Cost of Energy (LCOE) which calculates the cost of energy over the lifetime calculating the capex, fuel costs, maintenance, security and insurance costs. While it is true that the initial capital investment for solar power is quite high, the lifecycle cost of solar energy is not that high.

4) **Cannot be Built Anywhere** – This disadvantage of Solar Energy is present with other forms of Energy as well. Some forms of Energy are just better suited to some places. For example you can't build a nuclear plant on top of an earthquake prone region, you can't build a wind farm near the Dead Sea., etc.,

Limitations of Hydro Energy

1) **Environmental, Dislocation and Tribal Rights** – Large Dam construction especially in populated areas leads to massive Tribal Displacement, Loss of Livelihood and Religious Infringement as potentially sacred Land is occupied by the Government.

2) **Wildlife and Fishes get affected** – The Fishes are the most affected species from Dam Construction as the normal flow of the river is completely changed from its river character to a lake one. Submergence of land also leads to ecological destruction of the habitat of land based wildlife.

3) **Earthquake Vulnerability** – Large Dam Construction has been linked to increased propensity of Earthquakes. Massive Earthquakes in China and Uttarakhand in India were linked to the building of Massive Dams in these countries

4) **Siltation** – When water flows it has the ability to transport particles heavier than itself downstream. This has a negative effect on dams and subsequently their power stations, particularly those on rivers or within catchment areas with high siltation.

5) **Tail Risk, Dam Failure** – Because large conventional dammed-hydro facilities hold back large volumes of water, a failure due to poor construction, terrorism, or other cause can be catastrophic to downriver settlements and infrastructure. Dam failures have been some of the largest man-made disasters in history.

6) **Cannot be Built Anywhere** – This disadvantage of Hydro Energy is present with other forms of Energy as well. Some forms of Energy are just better suited to some places. For example you can't build a nuclear plant on top of an earthquake prone region, you can't build a wind farm near the Dead Sea etc. Hydro Energy can only be built in particular places though enough of those places exist globally.

7) **Long Gestation Time** – The time to construct a large hydro power project can take between 5-10 years which leads to time and cost overruns.

Limitations of Biomass Energy

1) **Pollution in case of Poor Technology** – Biomass Energy can lead to air pollution in the form of char if the biomass is not completely combusted. This happens in the case of biomass energy being produced in rural areas through bad technology.

2) **Feedstock Problems** – One of the biggest drawbacks of biomass energy is the problem of feedstock. The plants are forced to run at lower utilization leading to higher costs if feedstock is not available due to some reason like a drought.
3) **Good Management Required** – The operations of a biomass plant requires very good management otherwise it may run into losses or even in some cases have to shut down. It requires a skill of high order to run the plant optimally and make use of alternative feedstock in case the regular one is not available.

4) **Limited Potential** – Biomass Energy has smaller potential than compared to other forms of energy like solar, hydro, etc.,

5) **Controversial** – Large Biomass Plants like the one in Scotland have run into massive protests as people think it might lead to air pollution and health hazards if constructed near their homes.

Limitations of Wind Energy

1) **Low Persistent Noise** – There have been a large number of complaints about the persistent level of low level noise from the whirring of the blades of a wind turbine. There have been cases reported about animals on farms getting affected by wind turbine noise.

2) **Loss of Scenery** – The sight of giant 200 metres tall towers has drawn objections from neighbours about wind power leading to loss of scenery and beauty.

3) **Land usage** – Wind Turbines can sometimes use large amounts of land if not properly planned and built. The construction of roads to access the wind farms etc also takes up some land.

4) **Intermittent Nature** – Wind Power is intermittent in nature as it generates energy only when the wind blows. This problem can be solved with energy storage however this leads to additional costs.

Limitations of Geothermal Energy

1) **Long Gestation Time Leading to Cost Overruns** – The Gestation Time for permitting, financing, drilling, etc., can easily take 5-7 years to develop a geothermal energy field.

2) **Slow Technology Improvement** – Geothermal Energy has the potential to generate 100s of gigawatts of electricity through new techniques like Enhanced Geothermal Energy. However the technology improvement has been slow with setbacks.

3) Financing is the biggest problem in developing projects particularly for small project developers in this industry. There are few big geothermal developers like Chevron and Calpine.

4) **Regulations** – Drilling for new geothermal energy fields, buying of geothermal companies in foreign geographies faces innumerable hurdles.

5) **Limited Locations** – Geothermal Energy can only be built in places which have the geological characteristics favourable to generation of geothermal power.

Limitations of Tidal Energy

1) **High Initial Capital Investment** – Tidal Barrages require massive investment to construct a Barrage or Dam across a river estuary. This is comparable to construction of a massive dam for Hydro Power. This is perhaps the biggest disadvantage of this technology.

2) **Limited Locations** – The US DOE estimates that there are only about 40 locations in the world capable of supporting Tidal Barrages. This is because this Tidal Energy Technology requires sizable Tides for the Power Plant to be built. The limited number of locations is a big hurdle.

3) **Effect on Marine Life** – The operation of commercial Tidal Power Stations has known to moderately affect the marine life around the Power Plant. It leads to disruption in movement and growth of fishes and other marine life. Can also lead to increase in silt. Turbines can also kill fish passing through it.
4) **Immature Technology** – Except for Tidal Barrage, the other forms of Technology generating Tidal or Wave Power are quite immature, costly and unproven.

5) **Long Gestation Time** – The cost and time overruns can be huge for Tidal Power Plants leading to their cancellation.

6) **Difficulty in Transmission of Tidal Electricity** – Some forms of Tidal Power generate power quite far away from the consumption of electricity. Transportation of Tidal Energy can be quite cumbersome and expensive.

7) **Weather Effects** – Severe Weather like Storms and Typhoons can be quite devastating on the Tidal Power Equipment especially those places on the Sea Floor.

The Ministry of New and Renewable Energy, Government of India, has formulated an action plan to achieve a total capacity of 60 GW from hydro power and 175 GW from other RES by March, 2022, which includes 100 GW of Solar power, 60 GW from wind power, 10 GW from biomass power and 5 GW from small hydro power.

Present Indian and international energy scenario of conventional and RE sources

The World Energy Council has been developing and using World Energy Scenarios for over a decade to support its global member network of energy leaders, to clarify complexity, and to realise new opportunities for successfully managing global energy transition. World energy consumption is the total energy produced and used by the entire human civilization. Energy is essential for every activity of life. There is a strong positive correlation between energy use and the quality of life. At global level, per capita income of a country is directly proportional to the per capita energy consumption.

Country	Installed capacity Unit: TWh
United States	3,291
Russia	1,008
Japan	903
China	754
Germany	537
Canada	520
France	464
India	337
United Kingdom	321
Ukraine	253
Brazil	242
Italy	226

Table: 1. Installed capacity of conventional energy sources across globe

International energy scenario of conventional sources

Oil

Oil reserves at the end of 2018 totalled 1730 billion barrels, up 2 billion barrels with respect to 2017. The global R/P ratio shows that oil reserves in 2018 accounted for 50 years of current production.

Regionally, South & Central America has the highest R/P ratio (136 years) while Europe has the lowest (11 years). OPEC (Organization of the Petroleum Exporting Countries) holds 71.8% of global reserves. The top countries in terms of reserves are Venezuela (17.5% of global reserves), closely followed by Saudi Arabia (17.2%), then Canada (9.7%), Iran (9.0%) and Iraq (8.5%).

Global oil production increased by 2.2 million b/d in 2018. Growth was heavily concentrated in the US (2.2 million b/d), Canada (410,000 b/d) and Saudi Arabia (390,000 b/d) while oil production declined sharply in Venezuela (-580,000 b/d) and Iran (-310,000 b/d). OPEC production declined by 330,000 b/d while non-OPEC production increased by 2.6 million b/d. Oil consumption in 2018 grew by an above average 1.4 million b/d. China (680,000 b/d) and the US (500,000 b/d) accounted for the majority of this year's growth.

Sl.No	Country	Oil production - 2019 (bbl/day)
	World production	80,622,000
1	United States	15,043,000
2	Saudi Arabia (OPEC)	12,000,000
3	Russia	10,800,000
4	Iraq (OPEC)	4,451,516
5	Iran (OPEC)	3,990,956
6	China	3,980,650
7	Canada	3,662,694
8	United Arab Emirates (OPEC)	3,106,077
9	Kuwait (OPEC)	2,923,825
10	Brazil	2,515,459

Table: 2. Installed capacity of Oil across globe

Natural gas

World proved gas reserves in 2018 increased by 0.7 Tcm to 196.9 Tcm mainly as a result of increased reserves in Azerbaijan (0.8 Tcm). Russia (38.9 Tcm), Iran (31.9 Tcm) and Qatar (24.7 Tcm) are the countries with the biggest reserves. The current global R/P ratio shows that gas reserves in 2018 accounted for 50.9 years of current production, 2.4 years lower than in 2017. Middle East (109.9 years) and CIS (75.6 years) are the regions with the highest R/P ratio.

Country	Production in bcm
United States	864
Russia	741
Iran	232
Canada	188
Qatar	168
China	160
Norway	127
Australia	125
Saudi Arabia	98
Algeria	96
Turkmenistan	85
Indonesia	75

Table: 3. Installed capacity of Natural gas across globe

Coal

World coal reserves in 2018 stood at 1055 billion tonnes and are heavily concentrated in just a few countries: US (24%), Russia (15%), Australia (14%) and China (13%). Most of the reserves are anthracite and bituminous (70%). The current global R/P ratio shows that coal reserves in 2018 accounted for 132 years of current production with North America (342 years) and CIS (329 years) the regions with the highest ratio.

Sl.No	Country	Anthracite & bituminous	Subbituminous & lignite	Total
1	United States	111,338 (23.3%)	135,305 (31.4%)	246,643 (27%)

2	Russia	49,088 (10.3%)	107,922 (25.1%)	157,010 (17%)
3	China	62,200 (13%)	52,300 (12.2%)	114,500 (13%)
4	India	48,787 (10.2%)	45,660 (10.6%)	94,447 (10%)
5	Australia	38,600 (8.1%)	39,900 (9.3%)	78,500 (9%)
6	South Africa	48,750 (10.2%)	0 (0%)	48,750 (5%)
7	Ukraine	16,274 (3.4%)	17,879 (4.2%)	34,153 (4%)
8	Kazakhstan	28,151 (5.9%)	3,128 (0.7%)	31,279 (3%)
9	Poland	14,000 (2.9%)	0 (0%)	14,000 (2%)
10	Brazil	0 (0%)	10,113 (2.4%)	10,113 (1%)

Table: 4. Installed capacity of coal across globe

World coal reserves in 2018 stood at 1055 billion tonnes and are heavily concentrated in just a few countries: US (24%), Russia (15%), Australia (14%) and China (13%). Most of the reserves are anthracite and bituminous (70%). The current global R/P ratio shows that coal reserves in 2018 accounted for 132 years of current production with North America (342 years) and CIS (329 years) the regions with the highest ratio.

Global coal production increased by 4.3% in 2018, significantly above the 10-year average of 1.3%. Production growth was concentrated in Asia Pacific (163 mtoe) with China accounting for half of global growth and Indonesian production up by 51 mtoe. Coal consumption increased by 1.4% in 2018, the fastest growth since 2013. Growth was again driven by Asia Pacific (71 Mtoe), and particularly by India (36 Mtoe). This region now accounts for over three quarters of global consumption, while 10 years ago it represented two thirds.

Indian power sector

India’s power sector is one of the most diversified in the world. Sources of power generation range from conventional sources such as coal, lignite, natural gas, oil, hydro and nuclear power to viable non-conventional sources such as wind, solar, and agricultural and domestic waste. The national electric grid in India has an installed capacity of 368.79 GW as of 31 December 2019. Renewable power plants, which also include large hydroelectric plants, constitute 34.86% of India's total installed capacity. During the 2018-19 fiscal year, the gross electricity generated by utilities in India was 1,372 TWh and the total electricity generation (utilities and non utilities) in the country was 1,547 TWh. The gross electricity consumption in 2018-19 was 1,181 kWh per capita.

Sector	MW	% of Total
Central Sector	93,097	25.2%
State Sector	103,292	28.0%
Private Sector	173,039	46.8%
Total	**3,67,281**	

Table: 5. Contribution of various agencies to Indian power sector

Fuel	MW	% of Total
Total Thermal	2,30,701	62.8%
Coal	1,98,495	54.2%
Lignite	6,760	1.7%
Gas	24,937	6.9%
Diesel	510	0.1%
Hydro (Renewable)	45,699	12.4%
Nuclear	6,780	1.9%
RES* (MNRE)	86,759	23.5%
Total	**369,428**	

Table: 6. Contribution of various types of power to Indian power sector

Indian energy scenario of conventional sources

Coal

India's electricity sector consumes about 72% of the coal produced in the country. Coal consumption by utility power was 608 million tons in 2017-18. A large part of the Indian coal reserve is similar to Gondwana coal: it is of low calorific value and high ash content, with poor fuel value. On average, Indian coal has a gross calorific value (GCV) of about 4500 Kcal/kg, whereas in Australia, for example, the GCV is about 6500 Kcal/kg. The result is that Indian power plants using India's coal supply consume about 0.7 kg of coal per kWh of power generation, whereas in the United States thermal power plants consume about 0.45 kg of coal per kWh. In 2017, India imported nearly 130 Mtoe (nearly 200 million tons) of steam coal and cooking coal, 29% of total consumption, to meet the demand in electricity, cement and steel production. India is the world's second largest producer of coal after the People's Republic of China. The share of coal in both the energy mix and the power mix in India has been increasing since the 1970s and in 2017 coal provided 44% of the total primary energy supply (TPES) and 74% of electricity generation.

Supply and demand

According to the latest Geological Survey of India of April 2018, India holds proven coal reserves of 148.79 Gigatonnes (Gt) and total coal resources of 319.02 Gt. The proven lignite reserves amount to 6.54 Gt, while total lignite resources are 45.66 Gt.

Power generation, the largest consumer of coal, has various characteristics: India has coastal (31 GW) and inland plants (159 GW), which are usually located close to mines. India has 18 GW of power plants that are designed to only use imported coal. Power plants with a total capacity of 32 GW use a blend of domestic and imported coal. Plants using only domestic coal have a total capacity of 140 GW.

The National Thermal Power Corporation (NTPC) is India's largest coal power generator and one of the largest in the world, with 52 GW of installed coal generation capacity. Utilities owned by the state governments hold another 59 GW, while independent power producers (IPPs) account for 75 GW. Different public joint ventures in which NTPC is present account for 5 GW. Additionally, there are captive power plants with a total capacity of 54 GW, which produce electricity for own use in certain industries.

Oil

Oil remains an essential energy source for India. It is the second-largest source in the country's total primary energy supply (TPES) and the largest in its total final consumption (TFC). Oil demand has increased rapidly over the last several decades and India is now the third-largest oil-consuming country in the world.

Oil supply

In 2018 India's domestic oil production stood at 840 kb/d, which is 3% up from a decade ago, but 8% down from its peak of 910 kb/d in 2011. The estimated total volume of India's conventional hydrocarbon resources from 26 sedimentary basins is estimated to be around 47.8 billion tonnes of oil equivalent. According to the 2017/18 Indian Petroleum and Natural Gas Statistics report, India's proven reserves of crude oil and condensate as of April 2018 were around 595 Mt (around 4.4 billion barrels), which could potentially sustain production for about 14 years at current level. Location-wise, oil production in India comes primarily from three onshore states, Assam, Gujarat and Rajasthan, which together account for more than 96% of onshore outputs, and from the aged offshore Mumbai High Field. Some recent discoveries in Rajasthan and in the offshore Krishna-Godavari (KG) basin hold some potential.

Oil demand

Driven by rapid economic growth, oil demand in India has been growing for decades across all sectors. India's oil demand has risen strongly since 2008, with average demand growth close to 160 kb/d per year to reach 4.4 mb/d in 2017, which already represents 5% of global consumption. India's oil demand is expected to reach around 6 mb/d by 2024, representing 3.9% growth per annum, well ahead of the global average of 1.2%. The country is set to overtake China in the mid-2020s as the largest source of global oil

The tamilnadu state's peak power demand on March 19 touched 15,664 which is the maximum till date.

demand.

Natural gas

The present gas based installed capacity for power generation in the country is 24,937 MW and the Central Electricity Authority monitors a capacity of 23,883 MW (all natural gas based plants above 25 MW, excluding liquid fuel). Gas based power generation capacity of 14305 MW (11304 MW commissioned and 3001 MW under construction) is stranded due to non-availability of domestic gas, which is 51.2% of the gas based capacity (installed and under construction). The main reason for stranded gas based capacity is insufficient availability of domestic gas, particularly from Krishna Godavari Dhirubhai - 6 (KG D-6) basin. The supply of gas to power sector from this field is NIL since March, 2013.

Supply and demand

Natural gas supply has been growing more slowly than total energy demand. Hence, the share of natural gas in total primary energy supply (TPES) has fallen during the past decade. In power generation, the share of gas is declining and newly installed gas power capacity remains underutilised. The share of natural gas in total final consumption (TFC) is increasing, as industrial and residential consumption continue to grow.

In 2017 total gas supply was almost 60 bcm. Domestic production accounted for 54% of total supply and imports of LNG for the remaining 43%. With the exception of the period 2009-12, when production peaked at around 50 bcm, India's production has been stable at just above 30 bcm per year since the early 2000s.

Gas imports began in 2003 and have increased stepwise since, as India has expanded its LNG terminal capacity. In 2017 total natural gas imports were 27 bcm, of which 49% came from Qatar (Figure 11.3). India has diversified its supply sources in recent years and imported from more than 13 countries in 2017, including large shares from Nigeria, Equatorial Guinea and Australia.

International energy scenario of renewable sources

The leading countries for installed renewable energy in 2019 were China, the U.S., and Brazil. China was leading in renewable energy installations with a capacity of around 758.6 gigawatts. The U.S., in second place, had a capacity of around 264.5 gigawatts. Renewable energy is an important step in mitigating climate change and reducing the consequences caused by the phenomenon.

Country	Installed capacity in Gw
China	758.63
U.S.	264.5
Brazil	141.93
India	128.23
Germany	125.39
Canada	101
Japan	97.46
Italy	55.32
Russia	55.19
France	52.93

Table: 7. Installed capacity of renewable energy source across globe

Solar

1. Germany

At the end of May 2019, the cumulative solar power capacity of Germany reached 47.72 GW. The country has successfully met over 50% of the nation's daily energy demand from solar power.

2. China

Several centralized solar power projects of 2019 will get benefitted by China's government subsidies, like 1.7 billion Yuan (247.64 million dollars), involving the total installed capacity of 22.79 GW. According to reports from the National Energy Administration (NEA), 3,921 projects in 22 provinces and cities got approvals for these afore said subsidies.

3. Japan

Japan is still among the world's leaders in terms of total solar energy production, roughly around 55.5 GW in early 2019. The country could install nearly 155 GW by 2030 if things go according to their targets.

4. Italy

Likely to go some way to promoting renewable investment and helping Italy reach its 2030 targets are the seven competitive auctions to be held between 2019 and 2021, which include up to 4.8 GW in new PV and wind power plants, as well as 140 megawatts (MW) of hydro, biomass, and geothermal plants.

5. United States

According to the U.S Energy Information Administration, nearly 17% of electricity generation in the United States was hailed with the help of renewable power. All conditions remaining favourable, this perpetual growth might give rise to as much as four million solar installations by the year 2030. The U.S Department of Energy has also forecasted a 10% hike in their solar power generation by end of this year.

6. India

A country with one of the fastest-growing solar plants, India's solar installed capacity reached 28.18 GW in March 2019 and the country became the lowest cost producer of solar power in the world. The government had an initial target of 20 GW capacities for 2022, which was achieved four years ahead of schedule in 2018.

7. United Kingdom

Around 5% of Britain's total electricity generation was provided through solar by early 2019.

8. Australia

PV accounted for 5.2% of Australia's electrical energy production in early 2019, and as of March 2019, the country had over 12,035 MW of installed PV solar power, of which 4,068 MW were installed in the preceding 12 months. 59 solar PV projects with a combined installed capacity of 2,881 MW are also either under construction, constructed or due to start construction having reached financial closure.

9. France

Overall, the country's cumulative installed PV power surpassed an impressive 8.5 GW, with the newly installed PV capacity reaching 479 MW.

10. South Korea

According to the Ministry Of Trade, Industry & Energy, South Korea has successfully exceeded its Annual Deployment Target of 1.63 GW by installing 1.64 GW of Solar PV until July 2019. South Korea has plans to add 30 GW of PV by 2030, sundry of other steps have been undertaken to combat the country's overall former poor renewable performance, with 9% of that capacity to be developed in Saemangeum and 14GW of solar power energy to be installed before 2020.

Wind

1. China – installed capacity 221GW

It boasts the world's largest onshore windfarm in Gansu Province, which currently has a capacity of 7,965MW, five times larger than its nearest rival. The farm is currently only operating at 40% of its capacity, with a further 13,000MW to be installed leading to a grand total of 20,000MW (20GW) in 2020. This expansion is expected to cost $17.5bn.

2. US – installed capacity 96.4GW

The US is in second place with 96.4GW of installed capacity and is particularly strong in onshore wind power. Six of the largest 10 onshore windfarms are based in the US. These include the Alta Wind

Energy Centre in California, the world's second largest onshore wind farm with a capacity of 1,548MW, Shepherd's Flat Wind Farm in Oregon (845MW) and Roscoe Wind Farm in Texas (781.5MW).

3. Germany – installed capacity 59.3GW

Germany has the highest installed wind capacity in Europe with 59.3GW. Its largest offshore windfarms are the Gode Windfarms (phase 1 & 2), which have a combined capacity of 582MW. Germany is also home to the Nordsee One Offshore Wind farm, which has a capacity of 382MW and provides energy for 400,000 homes. According to Wind Europe, Europe installed 11.7GW of wind energy in 2018. Of this, Germany led the way with 29% of this capacity at a total of just under 3.4GW, with 2.4GW of this onshore and just under 1GW offshore.

4. India – installed capacity 35GW

India has the second highest wind capacity in Asia and is the only Asian country apart from China to make the list, with a total capacity of 35GW. The country has the third and fourth largest onshore wind farms in the world, the Muppandal windfarm in Tamil Nadu, Southern India (1,500MW) and the Jaisalmer Wind Park in Rajasthan, Northern India (1,064MW). The Indian government has set a target of installing 60GW of wind energy by 2022, with 25GW to be installed in the next three years.

5. Spain – installed capacity 23GW

Spain is a strong performer in wind energy, with a capacity of 23GW covering 18% of Spain's electricity supply. The country is fifth in the world despite none of its onshore or offshore wind farms being in the top 20 largest by capacity. The Spanish wind industry has actually been in a steep decline over the past few years. Just 104MW was added to its energy mix in 2016-2017 after nothing was added in 2015.

6. United Kingdom – installed capacity 20.7GW

The UK is the third European country on the list, with a total capacity of just over 20.7GW. The UK is particularly noteworthy in offshore wind, with six of the 10 highest-capacity offshore wind projects in the world. One of these is the Walney project off the coast of Cumbria, North West England. This is the largest offshore wind project in the world with Walney 1 & 2 (367MW) and Walney Extension (659MW) forming a grand total of 1,026MW. The Walney installation is set to be overtaken by the 1,218MW Hornsea One project in the North Sea when it is fully completed in 2020.

7. France – installed capacity 15.3GW

France is seventh on the list of top 10 wind energy countries by capacity. It is currently moving away from nuclear power, which previously delivered 75% of the country's energy needs, and will fill the gap by increasing its renewable budget to €71bn for the period 2019-2028. This will allow it to triple its onshore wind capacity by 2030. However, hostility to wind energy is "deeply rooted" in France, as much of the population considers wind turbines to be ugly and noisy.

8. Brazil – installed capacity 14.5GW

Brazil has the largest wind capacity in South America with 14.5GW and is expanding its capacity significantly. The most recent figures show that wind power had increased by 8.9% year-on-year in February 2019. Wind power is fourth place in Brazil's total energy mix, forming about 8% of Brazil's total energy capacity of 162.5GW.

9. Canada – installed capacity 12.8GW

Canada's renewable energy capacity stands at 12.8GW, with 566MW of new installed capacity added in 2018. This energy is generated by a total of 299 wind farms with 6,596 turbines. Ontario has the largest amount of wind energy, with just over 5GW installed. These include the 230MW Niagara Region Windfarm and the 199.5MW Amaranth Windfarm, north of Toronto. The largest wind farm in Canada is the Rivière-du-Moulin project in Quebec, which has a total capacity of 300MW. Wind accounts for about 5% of Canada's renewable energy supply, with hydroelectric way ahead at 67.5%.

10. Italy – installed capacity 10.1GW

In tenth place is Italy, which reached just over 10GW in wind energy capacity in 2018. Italy's wind industry is heavily concentrated in the south and on its islands. All of Italian energy company ERG's onshore wind capacity is based south of Rome for example, with Puglia (248.5MW) and Campania (246.9MW) being its strongest markets.

Geothermal Power

A total of 759 MW were added in 2019. Other countries represent an installed power generation capacity of 1,024 MW, bringing the total installed geothermal power generation capacity at the end of the year 2019 to 15,406 MW. We estimate that this is the largest annual growth to geothermal power generation capacity that we can follow at least back to 2000. It is though close to 2014, when growth the year prior was around 750 MW.

1. United States – 3,676 MW – with an additional 23 MW just added before the year-end
2. Indonesia – 2,133 MW – 185 MW added this year
3. Philippines – 1,918 MW – change of 50 MW is not quite clear, but might depend on work by EDC on existing plants
4. Turkey – 1,526 MW – 179 MW added in 2019, with still existing uncertainties regarding the FIT
5. New Zealand – 1,005 MW – no additions in 2019
6. Mexico – 962.7 MW – one addition of 27 MW, but net only a growth of 11.7 MW due to non-operational capacity.
7. Italy – 944 MW – with the current political climate, this number might not change much soon
8. Kenya – 861 MW – addition of 193.3 MW the largest expansion by country this year
9. Iceland – 755 MW – one addition of 5 MW replacing an old 3 MW plant
10. Japan – 601 MW – continued small-scale development and one larger addition, total 51.6 MW added

Biomass

The global capacity of biomass plants totaled 130 gigawatts.

Sl.No	Country	Biofuels Production - Ktoe (terawatt-hours)
1	North America	4598.07
2	United States	4429.62
3	South & Central America	2963.06
4	Brazil	2485.90
5	Europe	1854.87
6	Asia Pacific	1620.96
7	Indonesia	563.96
8	Germany	400.64
9	China	360.46
10	France	317.16

Table.8. Installed capacity of biomass across globe

Renewable energy scenario in India

Renewable energy (including large hydro) accounted for almost 36% of India's total power capacity mix at the end of the calendar year (CY) 2019, according to data from the Central Electricity Authority (CEA), and the Ministry of New and Renewable Energy (MNRE).

The country's total installed power capacity stood at about 371 GW as of December 31, 2019. Of this, renewables (including large hydro) accounted for about 133.2 GW, up from 122.8 GW last year, an 8.5% rise.

In 2018 the GoI announced an increased ambition of 227 GW renewable capacity by 2022 and 275 GW by 2027. At the United Nations' Climate Summit in New York on 23 September 2019, the Prime Minister of India announced a new target of 450 GW of renewable electricity capacity

Solar

Cumulative solar installations in the country stood at around 35.6 GW at the end of 2019, representing 9.6% of the total installed power capacity mix. It accounted for about 26.7% of all renewable energy in the country.

Wind

Wind power installations in the country have now touched 37.5 GW. This translates to 10.1% of the total installed power capacity.

Hydro

Cumulative hydropower installations moved up to about 50.1 GW and accounted for 13.5% of India's total installed power capacity. Of this, 4.67 GW or 1.26% were small hydropower.

Biomass

Bio power capacity share in the overall power mix was 2.66%. Cumulative installations at the end of 2019 stood at 9.86 GW.

Geothermal energy

Geothermal energy is thermal energy generated and stored in the Earth. India's geothermal energy installed capacity is experimental, and commercial use is insignificant. According to some estimates, India has 10,600 MW of geothermal energy available.