



A REVIEW ON ENERGY CONVERSION THROUGH RENEWABLE ENERGY SOURCES

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Abstract:

Renewable energy is a cornerstone of sustainable development, offering a cleaner, more sustainable alternative to traditional fossil fuels. One of the most abundant sources of renewable energy is solar power, which harnesses sunlight using photovoltaic cells to generate electricity. Wind power is another significant source, using turbines to convert the kinetic energy of wind into electricity. Hydropower, derived from flowing water, is another important renewable energy source, with large-scale hydroelectric plants providing a significant portion of the world's electricity.

Other forms of renewable energy include geothermal power, which utilizes heat from the Earth's interior, and biomass energy, derived from organic materials such as wood, crop residues, and animal waste. These renewable energy sources offer numerous environmental benefits, including reduced greenhouse gas emissions, improved air quality, and decreased reliance on finite fossil fuels. Additionally, renewable energy can enhance energy security by diversifying the energy mix and reducing dependence on imported fuels. As technologies continue to advance and economies of scale improve, renewable energy is becoming an increasingly viable and cost-effective option for meeting the world's energy needs.

Key Words:

Renewable Energy, Solar Energy, Climate Change, Wind Energy, Solar Photovoltaic Power Plant, Wind Power Plant, Hydro-Electricity, Geothermal Energy, Ocean Power

Introduction:

Renewable energy is a crucial component of our global energy transition, offering sustainable alternatives to fossil fuels. Unlike finite resources such as coal, oil, and natural gas, renewable energy sources are naturally replenished and can be used without depleting the Earth's resources. These sources include solar, wind, hydroelectric, geothermal, and biomass energy.

Solar energy, derived from the sun's rays, is abundant and widely accessible. It is captured using photovoltaic cells or solar thermal systems to produce electricity and heat. Wind energy, generated by the kinetic energy of moving air, is harnessed by wind turbines to generate electricity. Hydroelectric power utilizes the energy of flowing water, often through dams or turbines in rivers, to generate electricity. Geothermal energy, derived from the Earth's heat, is used for heating and electricity generation. Biomass energy is produced from organic materials such as plants, wood, and agricultural residues, which can be converted into heat, electricity, or biofuels.

Renewable energy offers numerous benefits, including reduced greenhouse gas emissions, improved air quality, and enhanced energy security. As technology advances and economies of scale improve, renewable energy is becoming increasingly cost-effective and competitive with traditional energy sources. Transitioning to renewable energy is essential for mitigating climate change, promoting sustainable development, and ensuring a cleaner, more sustainable future for generations to come.

Renewable Energy and Climate Change:

Presently, the term “climate change” is of great interest to the world at large, scientific as well as political discussions. Climate has been changing since the beginning of creation, but what is alarming is the speed of change in recent years and it may be one of the threats facing the earth. The growth rate of carbon dioxide has increased over the past 36 years (1979–2014) averaging about 1.4 ppm per year before 1995 and 2.0 ppm per year thereafter”. The United Nations Framework Convention on Climate Change defines climate change as being attributed directly or indirectly to human activities that alters

the composition of the global atmosphere and which in turn exhibits variability in natural climate observed over comparable time.

For more than a decade, the objective of keeping global warming below 2 °C has been a key focus of international climate. Since 1850, the global use of fossil fuels has increased to dominate energy supply, leading to a rapid growth in carbon dioxide emissions. Data by the end of 2010 confirmed that consumption of fossil fuels accounted for the majority of global anthropogenic greenhouse gas (GHG) emissions, where concentrations had increased to over 390 ppm (39%) above preindustrial levels.

Renewable technologies are considered as clean sources of energy and optimal use of these resources decreases environmental impacts, produces minimum secondary waste and are sustainable based on the current and future economic and social needs. Renewable energy technologies provide an exceptional opportunity for mitigation of greenhouse gas emission and reducing global warming through substituting conventional energy sources.

Classification of Renewable Energy:

Renewable energy sources can be classified into several categories based on their origin and characteristics. Here are the main classifications:

Solar Energy: This includes both solar photovoltaic (PV) and solar thermal energy. Solar PV systems convert sunlight directly into electricity using photovoltaic cells, while solar thermal systems use sunlight to heat water or other fluids to generate electricity or for heating purposes.

Wind Energy: Wind turbines convert the kinetic energy of wind into mechanical power, which is then converted into electricity. Wind energy is one of the fastest-growing renewable energy sources worldwide.

Hydropower: Hydropower, also known as hydroelectric power, harnesses the energy of flowing water to generate electricity. It is one of the oldest and most widely used renewable energy sources, with large-scale hydropower plants being a significant source of electricity globally.

Geothermal Energy: Geothermal energy utilizes heat from the Earth's interior to generate electricity or for heating purposes. It involves tapping into geothermal reservoirs and using steam or hot water to drive turbines and generate electricity.

Biomass Energy: Biomass energy is derived from organic materials such as wood, crop residues, and animal waste. It can be converted into heat, electricity, or biofuels through processes like combustion, gasification, or fermentation.

Ocean Energy: This includes tidal, wave, and ocean thermal energy. Tidal energy harnesses the energy of tides, wave energy captures the energy of ocean waves, and ocean thermal energy uses the temperature difference between the ocean's surface and deep water to generate electricity.

Each of these renewable energy sources has its advantages and limitations, and their suitability depends on factors such as location, resource availability, and technology maturity. Combining different renewable energy sources in a diversified energy mix can help achieve a more reliable and sustainable energy system.

Solar Power:

In the quest for sustainable and renewable energy sources, solar power plants have emerged as a beacon of hope, promising clean, abundant energy without the harmful emissions associated with fossil fuels. These power plants, also known as solar farms or solar parks, harness the sun's energy through photovoltaic (PV) panels or concentrated solar power (CSP) technology, marking a significant shift towards a more sustainable energy future.

One of the key advantages of solar power plants is their ability to generate electricity without producing greenhouse gas emissions. This makes them a crucial component in combating climate change and reducing our reliance on fossil fuels. Additionally, solar power plants have relatively low operating and maintenance costs once they are up and running, making them an economically viable option for sustainable energy generation.

Solar power plants come in various sizes, from small-scale installations on rooftops to large utility-scale projects covering vast expanses of land. The scalability and modular nature of these plants make them highly adaptable to different environments and energy needs, making them a versatile solution for increasing the share of renewable energy in the global energy mix.

The deployment of solar power plants has been steadily increasing in recent years, driven by advancements in technology, declining costs, and growing awareness of the need for sustainable energy solutions. Countries around the world are investing heavily in solar energy, recognizing its potential to transform the way we produce and consume electricity.

Despite these advantages, solar power plants face some challenges, such as intermittency and the need for energy storage solutions to ensure a steady supply of electricity. However, advancements in battery technology and grid integration are helping to overcome these challenges, making solar power plants an increasingly reliable and viable option for sustainable energy generation.

In conclusion, solar power plants represent a significant step towards a more sustainable and environmentally friendly energy future. With their ability to harness the sun's energy and convert it into electricity, these power plants have the potential to revolutionize the way we produce and consume energy, paving the way for a cleaner, greener planet for future generations.

Solar Photovoltaic Power Plant:

Photovoltaic power plants are also known as the PV. They convert sunlight into electricity. This type uses photovoltaic cells. These cells are made using silicon alloys. These panels are available in different forms. Some popular forms are crystalline solar panels and thin-film solar panels. PV options are preferred since it enables to store the solar energy into batteries. It can feed into the national grid as well. The PV plants will need inverter, for transforming the power from the DC into the AC.

As mentioned above, PV panels usually come from semiconductor material. When the photons of sunlight will hit the material, free electrons will be generated. The free electrons will flow through the material to generate a direct electrical current. The entire process is known as the photoelectric effect. The DC will be converted into AC by using an inverter, and finally, it will be fed into the grid. The PV panels are different from the solar thermal plants. They use photo effects. However, thermal plants use liquid heat-carrying ways. The benefit of PV panels is that they do not focus on energy. Instead, they convert photons into energy.



Wind Energy:

Wind power, a renewable energy source that has been harnessed for centuries, is gaining momentum as a key player in the transition to sustainable energy. Wind power harnesses the kinetic energy of the wind to generate electricity, offering a clean and abundant alternative to fossil fuels. Wind power is generated using wind turbines, which convert the wind's energy into electricity through the use of blades that rotate a generator.

One of the key advantages of wind power is its ability to generate electricity without producing greenhouse gas emissions or other harmful pollutants. This makes it a crucial tool in combating climate change and reducing our dependence on fossil fuels. Additionally, wind power has relatively low

operating costs once the turbines are installed, making it a cost-effective option for sustainable energy generation.

Wind power projects come in various sizes, from small-scale installations for individual homes or communities to large utility-scale projects that span hundreds of acres. These projects can be located on land or offshore, with offshore wind farms becoming increasingly popular due to the stronger and more consistent winds found at sea.

The deployment of wind power has been steadily increasing in recent years, driven by advancements in technology, declining costs, and growing awareness of the need for sustainable energy solutions. Countries around the world are investing heavily in wind power, recognizing its potential to transform the way we produce and consume electricity.

Despite its many advantages, wind power does face some challenges, such as intermittency and the need for energy storage solutions to ensure a steady supply of electricity. However, advancements in battery technology and grid integration are helping to overcome these challenges, making wind power an increasingly reliable and viable option for sustainable energy generation.

In conclusion, wind power represents a significant step towards a more sustainable and environmentally friendly energy future. With its ability to harness the power of the wind and convert it into electricity, wind power has the potential to revolutionize the way we produce and consume energy, paving the way for a cleaner, greener planet for future generations.



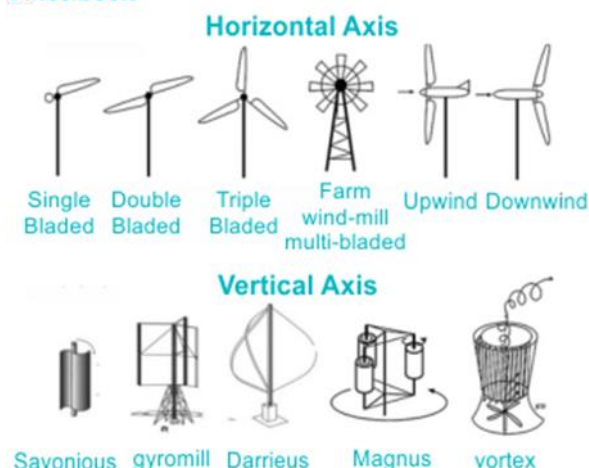
Working of Wind Power Plant:

So, how does a wind turbine work? The wind turbine works on the principle of conversion of kinetic energy of wind to mechanical energy used to rotate the blades of a fan connected to an electric generator. When the wind or air touches the blades (or) vanes of the windmill it the air pressure can be uneven, higher on one side of the blade and lower on the other. Hence, uneven pressure causes the blades to spin around the center of the turbine. The turbine does not operate at wind speeds above **55 mph** with the use of the controller. The rotor shaft of the turbine (ie., low speed and high speed) is interlinked with the gearbox which converts the speed from **30 to 60 rpm into 1000 to 1800 rpm**. As the gearbox consists of gears, to transmit mechanical energy. These speeds are most suitable to the generator for the generation of electricity. When the rotor of the turbine rotates it drives a generator through a setup gearbox causing the generator to produce electrical energy. Windmills are available in size from **100 KW to 36 MW** mainly used off-shore Now the engineers are designing **10 MW** of the wind turbine.

Types of Wind Power Plant (Wind Turbines)

There are two types of wind turbines

- Horizontal Axis Wind Turbines (HAWT)
- Vertical Axis Wind Turbine (VAWT)



Horizontal Axis Wind Turbines (HAWT): These turbines resemble windmills, with the tip of the shaft pointing in the direction of the wind. Smaller turbines are steered by wind vanes mounted on the building since they must face the wind. Wind sensors and servos are used with larger turbines to turn them.

Vertical Axis Wind Turbine (VAWT)

Mounted on the vertical shaft is the main root. This gets rid of the problems with horizontal wind turbines. As they require more space and are difficult to install. The subtypes consist of

- Darius Type turbine
- Savonious Type Turbine

The above figure shows different types of Wind turbines

Hydro-Electricity:

Hydroelectric power, generated by harnessing the energy of flowing water, is one of the oldest and most widely used forms of renewable energy. It involves the construction of dams or diversion structures to control the flow of water, which then passes through turbines to generate electricity. Hydroelectric power offers numerous benefits, making it a crucial component of the global energy mix.

One of the key advantages of hydroelectric power is its ability to generate electricity without producing greenhouse gas emissions or other harmful pollutants. This makes it a clean and sustainable alternative to fossil fuels, helping to mitigate climate change and reduce our reliance on finite energy sources. Additionally, hydroelectric power plants have a long lifespan and relatively low operating costs, making them a cost-effective option for sustainable energy generation.

Hydroelectric power plants come in various sizes, from small-scale installations in rivers or streams to large-scale projects that span entire river systems. These plants can also provide other benefits, such as flood control, irrigation, and water supply, making them a valuable resource for water management. The deployment of hydroelectric power has been steadily increasing in recent years, driven by advancements in technology, growing energy demand, and the need for sustainable energy sources. Countries around the world are investing in hydroelectric power, recognizing its potential to provide clean, reliable electricity to millions of people.

Despite its many advantages, hydroelectric power does face some challenges, such as the environmental and social impacts associated with large dams, including habitat disruption and displacement of communities. However, these challenges can be mitigated through careful planning, environmental impact assessments, and community engagement.

In conclusion, hydroelectric power represents a significant step towards a more sustainable and environmentally friendly energy future. With its ability to harness the power of water and convert it

into electricity, hydroelectric power has the potential to revolutionize the way we produce and consume energy, paving the way for a cleaner, greener planet for future generations.

Parts of Hydro Power Plant:

1. Penstock: Penstocks are like large pipes laid with some slope which carries water from intake structure or reservoir to the turbines. They run with some pressure so, sudden closing or opening of penstock gates can cause water hammer effect to the penstocks.

So, these are designed to resist the water hammer effect apart from this penstock is similar to normal pipe. To overcome this pressure, heavy wall is provided for short length penstock and surge tank is provided in case of long length penstocks.

Steel or Reinforced concrete is used for making penstocks. If the length is small, separate penstock is used for each turbine similarly if the length is big single large penstock is used and at the end it is separated into branches.

2. Surge Chamber: A surge chamber or surge tank is a cylindrical tank which is open at the top to control the pressure in penstock. It is connected to the penstock and as close as possible to the power house.



Whenever the power house rejected the water load coming from penstock the water level in the surge tank rises and control the pressure in penstock.

Similarly, when the huge demand is needed in power house surge tank accelerates the water flow into the power house and then water level reduces. When the discharge is steady in the power house, water level in the surge tank becomes constant. There are different types of surge tanks available and they are selected based on the requirement of plant, length of penstock etc.

3. Hydraulic Turbines Hydraulic turbine, a device which can convert the hydraulic energy into the mechanical energy which again converted into the electrical energy by coupling the shaft of turbine to the generator.

The mechanism in this case is, whenever the water coming from penstock strike the circular blades or runner with high pressure it will rotate the shaft provided at the center and it causes generator to produce electrical power.

Generally hydraulic turbines are of two types namely

- Impulse turbine
- Reaction turbine

Impulse turbine is also called as velocity turbine. Pelton wheel turbine is example for impulse turbine. Reaction turbine is also called as pressure turbine. Kaplan turbine and Francis turbine come under this category.



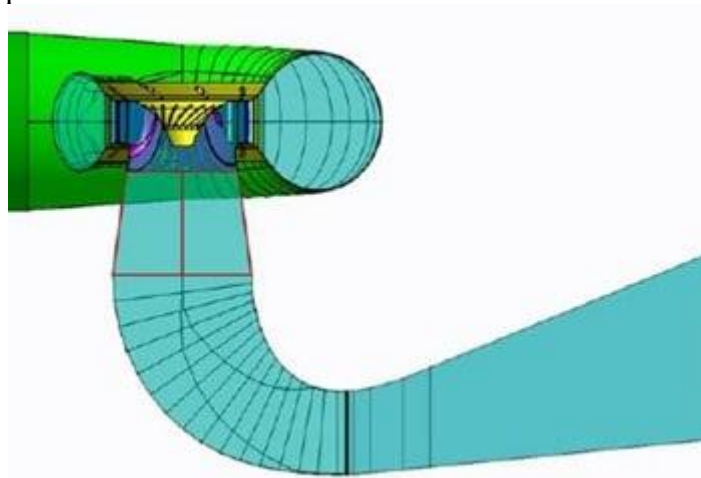
4. Power House Power house is a building provided to protect the hydraulic and electrical equipment. Generally, the whole equipment is supported by the foundation or substructure laid for the power house.

In case of reaction turbines some machines like draft tubes, scroll casing etc. are fixed with in the foundation while laying it. So, the foundation is laid in big dimensions.

When it comes to super structure, generators are provided on the ground floor under which vertical turbines are provided. Besides generator horizontal turbines are provided. Control room is provided at first floor or mezzanine floor.



5. Draft Tube If reaction turbines are used, then draft tube is a necessary component which connects turbine outlet to the tailrace. The draft tube contains gradually increasing diameter so that the water discharged into the tailrace with safe velocity. At the end of draft tube, outlet gates are provided which can be closed during repair works.



6. Tailrace Tailrace is the flow of water from turbines to the stream. It is good if the power house is located nearer to the stream. But, if it is located far away from the stream then it is necessary to build a channel for carrying water into the stream.

Otherwise the water flow may damage the plant in many ways like lowering turbine efficiency, cavitation, damage to turbine blades etc.

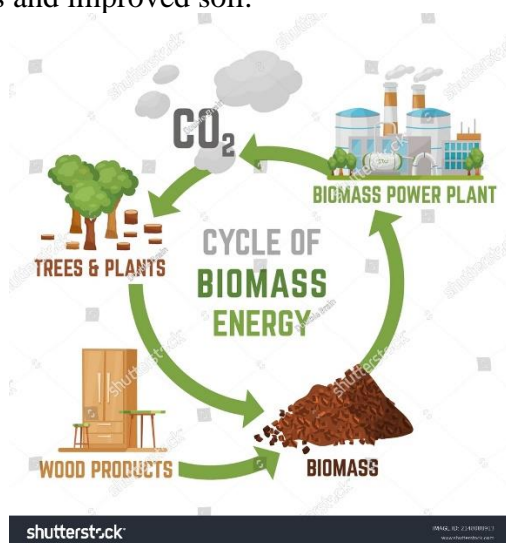
This is because of silting or scouring caused by unnecessary flow of water from power house. Hence, proper design of tailrace should be more important.

Hydropower Environmental and Social Impact:

Hydropower generation does not produce greenhouse gases and thus mostly termed as a green source of energy. Nonetheless, it has its advantages and disadvantages. It improves the socio-economic development of a country; but, also considering the social impact, it displaces a lot of people from their homes to create it, though they are compensated but are not enough. The exploitation of the sites for hydropower such as, reservoirs that are often artificially created leading to flooding of the former natural environment. In addition, water is drained from lakes and watercourses and transported through channels over large distances and to pipelines and finally to the turbines that are often visible, but they may also go through mountains by created tunnels inside them. Hydroelectric structures affect river body's ecology, largely by inducing a change into its hydrologic characteristics and by disturbing the ecological continuity of sediment transport and fish migration through the building of dams, dikes and weirs. In countries where substantial plants or tree covers are flooded during the construction of a dam, there may be formation of methane gas when plants start rotting in the water, either released directly or when water is processed in turbines.

Bioenergy Environmental and Social Impact:

The use of biological components (plant and animal source) to produce energy has always been a cause of worry especially to the general public and as to whether its food produce is to be used to provide fuel since there are cases of food aid needed around the world in deprived countries. About 99.7% of human food is obtained from the terrestrial environment, while about 0.3% comes from the aquatic domain. Most of the suitable land for biomass production is already in use. Current studies have underlined both positive and negative environmental and socio-economic effects of bioenergy. Like orthodox agriculture and forestry systems, bioenergy can worsen soil and vegetation degradation related with the overexploitation of forest, too exhaustive crop and forest residue removal, and water. Diversion of crops or land into bioenergy production can induce food commodity prices and food security Proper operational management, can bring about some positive effects which includes enhanced soil carbon increases and improved soil.



Geothermal Energy:

Geothermal energy is obtained naturally from the earth's interior as heat energy source. The origin of the heat is linked with the internal structure of the planet and the physical processes occurring there. Although heat is present in the earth's crust in huge quantities, not to mention the deepest parts, it is unevenly distributed, rarely concentrated, and often at depths too great to be exploited mechanically. Geothermal gradient averages about 30 °C/km. There are areas of the earth's interior which are accessible by drilling, and where the gradient is well above the average gradient. Heat is mined from geothermal reservoirs using wells and other means. Reservoirs that are naturally adequately hot and permeable are called hydrothermal reservoirs, while reservoirs that are satisfactorily hot but are improved with hydraulic stimulation are called enhanced geothermal systems (ESG). Once drawn to the surface, fluids of various temperatures can be used to generate electricity and other purposes that require the use of heat energy.

There are three main types of geothermal energy systems:

Direct Use Systems: These systems use hot water from geothermal reservoirs (typically below 300°F or 150°C) for heating buildings, growing plants in greenhouses, drying crops, heating water at fish farms, and other agricultural and industrial processes.

Geothermal Heat Pumps: Also known as ground-source heat pumps, these systems use the relatively constant temperature of the ground just a few feet below the surface to heat and cool buildings. They are highly efficient and can significantly reduce energy costs for heating and cooling.

Geothermal Power Plants: These plants use the heat from deep within the Earth (typically above 300°F or 150°C) to produce steam, which then drives turbines connected to generators to produce electricity. There are several types of geothermal power plants, including dry steam, flash steam, and binary cycle plants, depending on the temperature of the resource.

Geothermal energy offers several advantages, including:

Reliability and Availability: Unlike solar and wind energy, which are intermittent, geothermal energy is available 24/7, making it a reliable source of baseload power.

Low Emissions: Geothermal power plants emit very low levels of greenhouse gases compared to fossil fuel power plants.

Small Footprint: Geothermal power plants have a relatively small land footprint compared to other power plants, making them suitable for locations where space is limited.

Cost-Effectiveness: While the upfront costs of developing geothermal resources can be high, the operating costs are relatively low, resulting in long-term cost savings.

Despite these advantages, geothermal energy faces some challenges, including the high upfront costs of exploration and drilling, limited suitable locations for power plant development, and the potential for resource depletion if not managed sustainably.

Overall, geothermal energy has the potential to play a significant role in our transition to a more sustainable energy future, providing clean, reliable, and cost-effective energy for generations to come.



Ocean Power:

Ocean power, often referred to as marine or ocean energy, encompasses a range of technologies that harness the renewable energy potential of the oceans. This includes tidal energy, wave energy, and



ocean thermal energy conversion (OTEC). These forms of energy offer immense potential to contribute to the global energy mix, providing clean, renewable power without the carbon footprint associated with fossil fuels.

Tidal energy is generated by harnessing the kinetic energy of tidal currents. This can be achieved through underwater turbines similar to those used in wind power, which are placed in areas with strong tidal flows. Wave energy, on the other hand, captures the energy of ocean waves using devices that convert the up-and-down motion of the waves into electricity. Both tidal and wave energy have the advantage of being predictable and relatively consistent, making them reliable sources of renewable energy.

Ocean thermal energy conversion (OTEC) utilizes the temperature difference between the warm surface waters of the ocean and the colder deep waters to generate electricity. This technology is still in the early stages of development but has the potential to provide a constant source of clean energy in tropical regions where the temperature differential is greatest.

One of the key advantages of ocean energy is its vast potential. The world's oceans cover more than 70% of the Earth's surface, providing an abundant and largely untapped source of renewable energy. Additionally, ocean energy is highly predictable, with tides and waves following regular patterns, making it a reliable source of power.

Despite its potential, ocean energy faces several challenges, including high costs, technological limitations, and environmental impacts. However, ongoing research and development efforts are working to overcome these challenges, making ocean energy an increasingly viable option for sustainable energy generation.

In conclusion, ocean energy represents a promising frontier in the field of renewable energy. With its vast potential and reliability, ocean energy has the potential to play a significant role in the transition to a more sustainable and environmentally friendly energy future.

Conclusion:

In conclusion, the transition to renewable energy is not just a necessary step to combat climate change; it is also a remarkable opportunity to reshape our energy landscape for the better. The diverse range of renewable energy sources, from solar and wind to hydroelectric and ocean power, offers a sustainable path towards meeting our energy needs while minimizing environmental impact.

Renewable energy technologies have made significant strides in recent years, with falling costs and increasing efficiency making them increasingly competitive with fossil fuels. This trend is expected to continue, driven by ongoing technological advancements and growing recognition of the urgent need to reduce greenhouse gas emissions.

However, the transition to renewable energy is not without its challenges. The intermittent nature of some renewable sources, such as solar and wind, requires the development of energy storage solutions to ensure a reliable and stable power supply. Additionally, the deployment of renewable energy technologies must be accompanied by smart policies, effective regulations, and robust infrastructure to support their integration into existing energy systems.

Despite these challenges, the benefits of renewable energy far outweigh the costs. Not only does renewable energy reduce our reliance on finite fossil fuels and mitigate the impacts of climate change, but it also creates new economic opportunities, promotes energy security, and improves public health by reducing air pollution.

As we look to the future, it is clear that renewable energy will play a central role in shaping our energy future. By investing in renewable energy technologies, we can build a more sustainable, resilient, and equitable energy system that benefits both people and the planet.

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