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[ijirset@gmail.com](mailto:ijirset@gmail.com)

[www.ijirset.com](http://www.ijirset.com)

# **A Review on Renewable Energy System**

**S. Srinivasu<sup>1</sup>, M.V. Kamal Sai<sup>2</sup>, K. Shyam<sup>3</sup>, S. Aravind<sup>4</sup>, Kona Ram Prasad<sup>5</sup>**

Students, Department of Mechanical Engineering, N. S. Raju Institute of Technology, Affiliated to JNTUGV,  
AP., India<sup>1,2,3,4</sup>

Assistant Professor, Department of Mechanical Engineering, N. S. Raju Institute of Technology, Affiliated to JNTUGV,  
AP., India<sup>5</sup>

**ABSTRACT:** The growing demand for sustainable energy solutions has led to the development of renewable energy systems capable of providing reliable, environmentally friendly power. This study focuses on the design and implementation of a renewable energy system that integrates solar, wind, and energy storage technologies to create a self-sustaining, off-grid power solution. The system leverages photovoltaic (PV) solar panels, small-scale wind turbines, and advanced battery storage to meet fluctuating energy demands while minimizing environmental impact. Energy management systems (EMS) are employed to optimize the generation, storage, and consumption of energy, ensuring efficiency and reliability. The hybrid nature of the system allows it to adapt to varying weather conditions, providing consistent energy even in the absence of one power source. The use of renewable resources such as solar and wind reduces dependence on fossil fuels, lowering greenhouse gas emissions and promoting energy independence. This paper presents a comprehensive analysis of system performance, cost-effectiveness, and potential applications in remote or off-grid areas, demonstrating the viability of integrated renewable energy solutions for sustainable power generation.

Renewable energy resources are natural sources of energy that won't run out and can be used over and over. They come from things like sunlight, wind, water, and plants. Unlike fossil fuels (like coal and oil), which can take millions of years to form and are limited, renewable energy sources are naturally replenished quickly

Each type of renewable energy is at a different stage in its journey to becoming widely used. They vary in cost, availability, and impact on reducing greenhouse gas emissions. It is not hidden anymore that India has a vast supply of renewable resources and it has one of the largest programs in world for deploying renewable energy products and systems. India is the only country in the world to have an exclusive ministry for renewable energy development, the Ministry of New and Renewable Energy (MNRE) which has launched one of the world's largest and ambitious programs on renewable energy.

## **I. INTRODUCTION**

Renewable energy (or green energy) is energy from renewable natural resources that are replenished on a human timescale. The most widely used renewable energy types are solar energy, wind power, and hydropower. Bioenergy and geothermal power are also significant in some countries. Some also consider nuclear power a renewable power source, although this is controversial. Renewable energy installations can be large or small and are suited for both urban and rural areas. Renewable energy is often deployed together with further electrification.

A renewable energy system refers to the generation of power using natural resources that are continually replenished, such as sunlight, wind, rain, geothermal heat, and tides. Unlike fossil fuels, which are finite and contribute to environmental pollution, renewable energy sources offer a sustainable, clean alternative that helps reduce greenhouse gas emissions and mitigate climate change. Renewable energy resources are natural sources of energy that can be used again and again without running out. Unlike fossil fuels like coal, oil, and natural gas, which can take millions of years to form, renewable energy sources are constantly replenished. Examples include sunlight, wind, water, and heat from inside the Earth. Using renewable energy is important because it helps reduce pollution, saves natural resources, and creates a cleaner environment. Renewable energy is becoming more popular as a way to power our world sustainably, as these sources are better for the planet and help fight climate change.

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## II. DESCRIPTION OF RENEWABLE ENERGY SOURCES

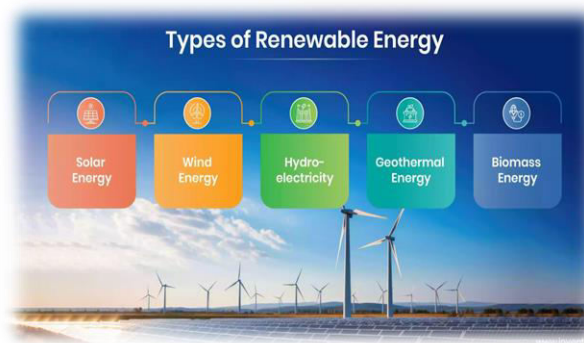


Fig. 1. Types of renewable energies

### Solar Energy:



fig.2 Solar energy

Solar energy comes from the sun's light, which can be converted into electricity or heat. Solar panels capture sunlight and convert it into electricity using solar cells. Solar energy is a renewable energy source harnessed from the sun's radiation. It can be converted into electricity or heat through technologies like photovoltaic (PV) solar panels and solar thermal systems.

1. Photovoltaic Solar Panels: These convert sunlight directly into electricity using semiconductor materials. When sunlight hits the panels, it excites electrons in the material, creating an electric current.
2. Solar Thermal Systems: These capture sunlight to heat a fluid, which can then be used for heating or generating steam to power turbines and produce electricity.

Solar energy is considered environmentally friendly because it produces no greenhouse gas emissions during operation. It's also a sustainable resource, as the sun will continue to shine for billions of years. The main challenges include the intermittent nature of sunlight (only available during the day or in sunny conditions) and the need for storage or backup systems to ensure a consistent power supply. Solar power is a key player in the transition to cleaner energy, helping reduce reliance on fossil fuels and combat climate change.

### Wind Energy:



Fig.3 Wind Energy

Wind energy is a small but fast-growing fraction of electricity production. It accounts for 5 percent of global electricity production and 8 percent of the U.S. electricity supply.

WindEnergy capacity surpasses 743 gigawatts, which is more than is available from grid-connected solar energy and about half as much as hydropower can provide. Nearly three-quarters of those 651 gigawatts comes from wind farms in five countries: China, the U.S., Germany, India, and Spain. Wind energy capacity in the Americas has tripled over the past decade. Wind energy is generated by the movement of air (wind).

Wind Turbines: Large wind turbines with blades spin when wind blows, turning a generator to create electricity.

Uses: Powering homes and communities, especially in open areas or offshore.

### Hydropower:

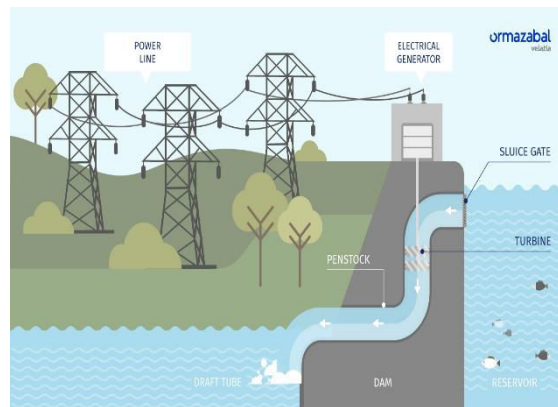


Fig.4 Hydropower

Hydropower uses the energy of flowing water, usually from rivers or dams. Dam: This is the civil construction, mainly made of concrete, that allows the volume of water retained for use by the power plant operator to be maintained. Some of the most impressive ones raise the water fall by hundreds of meters.

Reservoir: This is the water storage facility that houses the installation and collects the inflow stream.

Sluice gates: These are the movable elements that open and close to allow water to pass through them.

Penstock: A pipeline through which water is conveyed on its way to the power generation.

Turbines: These are the engines that the water feeds as it passes through, allowing mechanical energy to be generated.

Electric generators: These are the elements responsible for converting the mechanical energy of the turbines into electrical energy.

Power line: It transports the newly generated electricity to the different consumption points.

Draft tube: This is the outlet for all hydraulic flow used during the electricity generation process.

Hydroelectric Dams: Water flows through turbines in a dam, generating electricity show in fig.4. Providing electricity to large areas, often more consistent than solar or wind.

### Biomass Energy:

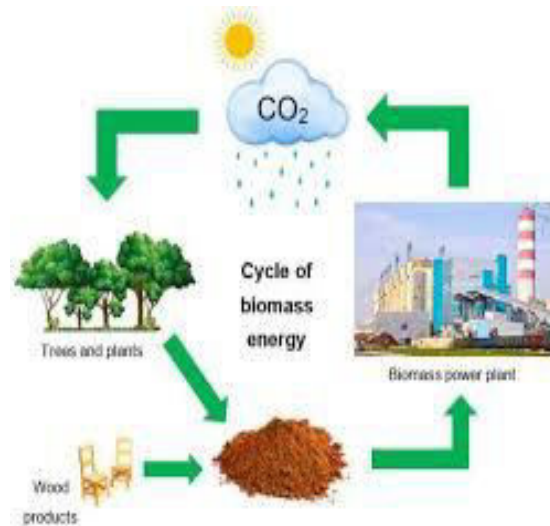


Fig.5 Biomass energy

Biomass energy is produced from organic materials like plants, wood, and waste.

Biomass feedstocks include dedicated energy crops, agricultural crop residues, forestry residues, algae, wood processing residues, municipal waste, and wet waste (crop wastes, forest residues, purpose-grown grasses, woody energy crops, algae, industrial wastes, sorted municipal solid waste [MSW], urban wood waste, and food waste). Forest biomass feedstocks fall into one of two categories: forest residues left after logging timber (including limbs, tops, and culled trees and tree components that would be otherwise unmerchantable) or whole-tree biomass harvested explicitly for biomass. Dead, diseased, poorly formed, and other unmerchantable trees are often left in the woods following timber harvest. This woody debris can be collected for use in bioenergy, while leaving enough behind to provide habitat and maintain proper nutrient and hydrologic features. There are also opportunities to make use of excess biomass on millions of acres of forests. Harvesting excessive woody biomass can reduce the risk of fire and pests, as well as aid in forest restoration, productivity, vitality, and resilience. This biomass could be harvested for bioenergy without negatively impacting the health and stability of forest ecological structure and function

Biofuel Production: Biomass is burned or processed into biofuels like ethanol, used for heating or fuel. Uses Heating, electricity, and even fueling vehicles.

### Geothermal Energy:

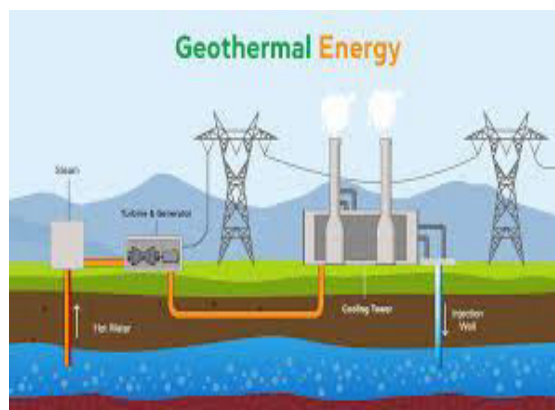


Fig.6 Geothermal energy

Geothermal energy comes from the heat within the earth. Geothermal Plants: Wells are drilled into the ground to access hot water and steam, which is used to drive turbines for electricity. This is an easy alternative to access hot water, but it applies to the areas where hot springs and underground reservoirs are nearest. A production facility, a downhole, and circulation pumps or wells are used to bring up the water. A downhole consists of two types that are line shaft pump systems and submersible pumps. Just as both types have been in practice for a long time, the line shaft pumping system is preferred over the submersible pumps. This is because it is affordable, and submersible pumps require 800 feet of dept for the setting.

Furthermore, A mechanical facility with the transmission pipeline, heat exchanger, and the cooling system directs the necessary heat to its intended use. The transmission pipeline can either be a single pipe or a two-pipe system. The single pipe is a once-through system where the vapour is disposed of after use. This is generally preferred when geothermal energy is overflowing and when the water is pure or clean. And the two-pipe system recirculates the vapour where the residual heat is conserved. Uses: Heating buildings, generating electricity, and hot water.

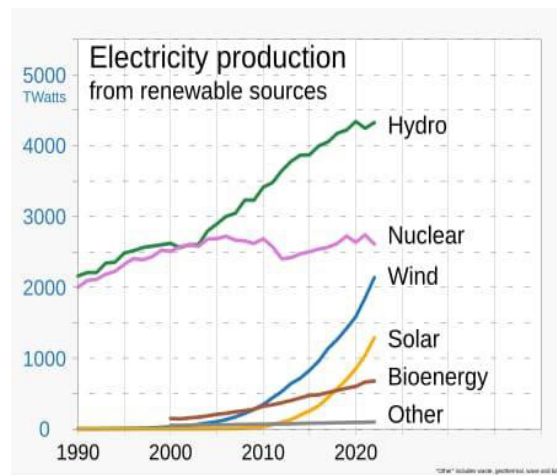


Fig.7 electricity from renewable sources

Renewable energy sources, especially solar photovoltaic and wind, are generating an increasing share of electricity as show in fig.7

The results of a recent review of the literature concluded that as greenhouse gas (GHG) emitters begin to be held liable for damages resulting from GHG emissions resulting in climate change, a high value for liability mitigation would provide powerful incentives for deployment of renewable energy technologies

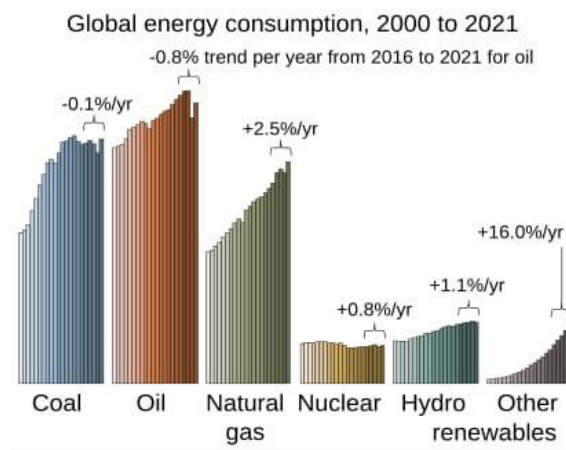


Fig.8 Global energy consumption

Coal, oil, and natural gas remain the primary global energy sources even as renewables have begun rapidly increasing as show in fig.8.

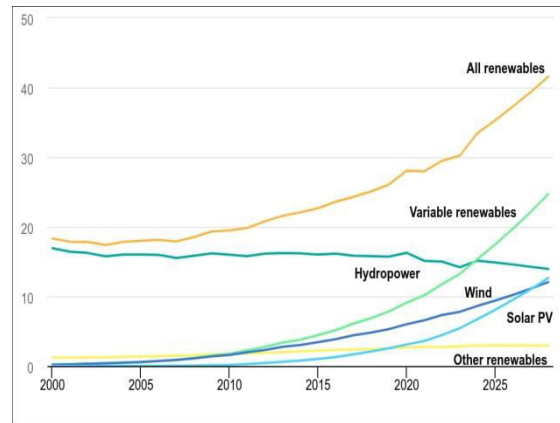


Fig.9 share of renewable electricity generation by technology,2000-2028

Electricity generation from wind and solar PV indicate potential generation including current curtailment rates in above fig.9. However, it does not project future curtailment of wind and solar PV, which may be significant in a few countries by 2028

After a transitional period, renewable energy production is expected to make up most of the world's energy production. In 2018, the risk management firm, DNV GL, forecasts that the world's primary energy mix will be split equally between fossil and non-fossil sources by 2050. Middle eastern nations are also planning on reducing their reliance fossil fuel. Many planned green projects will contribute in 26% of energy supply for the region by 2050 achieving emission reductions equal to 1.1 Gt CO<sub>2</sub>/year. Some studies say that a global transition to 100% renewable energy across all sectors – power, heat, transport and industry – is feasible and economically viable.

One of the efforts to decarbonize transportation is the increased use of electric vehicles (EVs). Despite that and the use of biofuels, such as Bioject, less than 4% of transport energy is from renewables. Occasionally hydrogen fuel cells are used for heavy transport. Meanwhile, in the future electro fuels may also play a greater role in decarbonizing hard-to-abate sectors like aviation and maritime shipping.

Solar water heating makes an important contribution to renewable heat in many countries, most notably in China, which now has 70% of the global total (180 GWth). Most of these systems are installed on multi-family apartment buildings and meet a portion of the hot water needs of an estimated 50–60 million households in China. Worldwide, total installed solar water heating systems meet a portion of the water heating needs of over 70 million households.

Heat pumps provide both heating and cooling, and also flatten the electric demand curve and are thus an increasing priority. Renewable thermal energy is also growing rapidly. About 10% of heating and cooling energy is from renewables.

### III. MINIMUM ENERGY PERFORMANCE STANDARDS LEVELS IN MANUFACTURING COUNTRIES AND MARKET SHARE OF AIR CONDITIONERS IN KENYA COMPARED TO KENYA ENERGY EFFICIENCY LABEL LEVELS, 2024

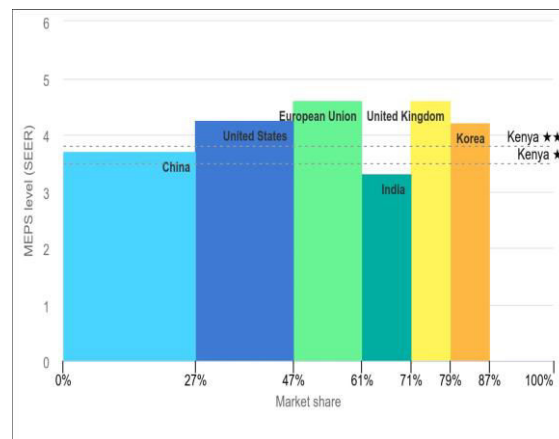


Fig.10. Minimum energy performance standards levels in manufacturing countries and market share of air conditioners

**China** continues to lead in terms of renewable electricity capacity additions, with 160 GW added in 2022, almost half of all global deployment. The 14th Five-Year Plan for Renewable Energy, released in 2022 as show in fig.10, provides ambitious targets for renewable energy use, which should spur investment in the coming years.

The **European Union** is accelerating solar PV and wind deployment in response to the energy crisis, with more than 50 GW added in 2022, an almost 45% increase compared to 2021s as show in fig.10. New policies and targets proposed in the REPowerEU Plan and The Green Deal Industrial Plan are expected to be important drivers of renewable energy investments in the coming years.

The **United States** announced important new funding in 2022 under the IRA, which is expected to advance deployment of renewables in the medium term, and to boost investment in both power plants and equipment manufacturing.

**India** remains committed to its ambitious target of reaching 500 GW of non-fossil power capacity in 2030 as show in fig.10. In April 2023, it announced a plan to auction 50 GW of new capacity annually to fulfil this goal.

Renewables, including solar, wind, hydropower, biofuels and others, are at the Centre of the transition to less carbon-intensive and more sustainable energy systems. Generation capacity has grown rapidly in recent years, driven by policy support and sharp cost reductions for solar photovoltaics and wind power in particular.

The deployment of renewables in the power, heat and transport sectors is one of the main enablers of keeping the rise in average global temperatures below 1.5°C. In the Net Zero Emissions by 2050 scenario, renewables allow electricity generation to be almost completely decarbonized. Meanwhile, renewable transport fuels and renewable heat contribute to significant emissions reductions in transport, buildings and industry.

Renewables play a critical role in clean energy transitions. The deployment of renewables for electricity generation, for heat production for buildings and industry, and in transport is one of the main enablers of keeping average global temperature rise below 1.5°C. Modern bioenergy is today the largest source of renewable energy globally, with a more than 50% share of global use in 2022. Bioenergy is discussed separately, and this page is dedicated to other renewable technologies.

Recent progress has been promising, and 2022 was a record year for renewable electricity capacity additions, with annual capacity additions amounting to about 340 GW. Key policies announced in 2022, especially REPowerEU in the European Union, the Inflation Reduction Act (IRA) in the United States and China's 14th Five-Year Plan for Renewable Energy, will lend further support to accelerate renewable electricity deployment in the coming years.



Solar PV is today the only renewable energy technology on track with the Net Zero Emissions by 2050 (NZE) Scenario. Wind, hydro, geothermal, solar thermal and ocean energy use needs to expand significantly faster in order to get on track. Non-bioenergy renewables need to increase their share of total energy supply from close to 5% today to approximately 17% by 2030 in the NZE Scenario. To achieve this, annual renewable energy use must increase at an average rate of about 13% during 2023-2030, twice as much as the average over the past 5 years.

#### IV. HOW TO MAKE RENEWABLE ENERGY STABLE FOR POWER GRIDS



Fig.11 How to make renewable energy stable for power grids

The introduction of renewable energy sources into local power grids often creates an unstable flow of power due to the Non steady generation rates of renewables. This could adversely affect power distribution within the power grid, overpowering some portions while underpowering others. Neither is desirable for utility companies, nor for consumers of electric power. Therefore, it is necessary to compensate for these unstable power sources in a way that provides stable power as show in fig.11.

An effective solution is to store the excess power generated by the renewable sources when they produce at rates that exceed demand, then feed it back into the power distribution grid when consumer demand exceeds the generation rates. Without this power-leveling capability, renewable sources would not be a viable option.

An innovative solution to this need for storage has been developed by Wartsila in its Grid Solv Quantum battery energy storage system (BESS) enclosures. To best service utility owners' requests for BESS installation projects, Wartsila and Shackelford General Contractors have teamed to offer best-in-class solutions. For these projects, Shackelford performs the site, structural and electrical design and construction, while Wartsila furnishes and maintains the electrical equipment. Shackelford has contracted with Hanson to perform civil and structural engineering services for these facilities.

The small footprint occupied by these installations presents unique site design challenges, including the need to maintain critical offsets between electrical equipment, fences, buildings and other features while keeping a compact yet maintainable installation. Other key considerations are the safety of the personnel using and maintaining the equipment, firefighting accommodations and vehicular access. Because these units are very heavy, a substantial crane is required to set them, and crane access and accommodation is a key component of site planning for BESS sites. Structural designs for the installations can be slabs on grade, deep foundations or strip foundations, depending on site-specific considerations.

The strength of this Wartsila-Shackelford-Hanson engineering, procurement and construction (EPC) team is in its ability to work effectively within all 50 states and develop appropriate and cost-effective solutions for any type of site

or group of sites. With the power-leveling capability offered by Wartsila's leading energy storage system and this EPC team, renewable sources can be used as a cost-effective and stable supplement to carbon-based power generation methods.

### V. OUTLOOK FOR INDIA’S RENEWABLE ENERGY IN 2024 IS POSITIVE

The National Green Hydrogen Mission with an outlay of Rs 19,744 crore was approved in January. A part from solar and wind energy, India has increased its focus on green hydrogen in a big way to reduce dependence on fossil fuels, mainly diesel, which is required for long haul vehicles. India is a diesel-based economy in a way that most of the commercial vehicles for passenger and freight services are using diesel as the fuel. India will witness more than 83 per cent increase in investments in renewable energy projects to around \$16.5 billion in 2024 as the country focuses on energy transition to reduce carbon emissions, according to power ministry estimates. This is in line with the ambitious target of having 500 GW of renewable energy by 2030 and its resolve to reduce overall power generation capacity from fossil fuels to less than 50 per cent.

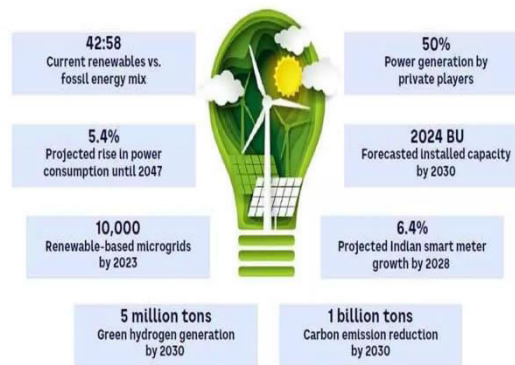


Fig.12 Outlook for India’s renewable energy in 2024 is positive

India has committed a net zero emission target by 2070. However, Union Power and New & Renewable Energy Minister R.K. Singh has often said that around 65 per cent power generation capacity would be from non-fossil fuels by 2030 and that would be higher than the set target of 50 per cent. In an interview, Singh said, "India is likely to witness 25 GW of renewable energy capacity addition entailing an investment of Rs. 1,37,500 crores in 2024, which would be higher than 13.5 GW with an investment of Rs. 74,250 crores seen in 2023."

### VI. FUTURE OF RENEWABLE ENERGY SECTOR IN INDIA



Fig.13.Future of Renewable Energy Sector in India

The Indian government has set an ambitious goal of adding 500 GW of renewable capacity by 2030. To achieve this goal, India needs to add a minimum of 25 Gigawatt of renewable energy capacity every year for eight years. This requires an investment of INR **1,25,000 crore**, considering that requirement of INR **5 crore per MW** of capacity addition. India currently has about 173 Gigawatt of clean energy capacity including large hydro and nuclear power. This blog aims to provide entrepreneurs with an overview and potential renewable energy business ideas. The Union Minister for Power, RK Singh has informed that the investments in renewable energy sector could total around USD 25 billion in 2023. RK Singh also informed that, solar manufacturing capacity worth INR 8,780 crore is under construction including polysilicon and module. He stated that the government is bringing the Production Linked Incentive scheme worth ₹19,500 crore to develop 40 GW capacity. This has created a plethora of opportunities in the renewable energy sector. Investment in India's renewable energy sector grew more than 125% Year on Year to reach a record USD 15 billion in 2022. Additionally, India has already crossed 11 GW capacity installation in nine months of 2022.

## VII. IMPORTANCE OF RENEWABLE ENERGY SECTOR TO INDIA

Renewable energy plays a crucial role in addressing India's energy security and sustainability challenges. India is heavily dependent on imported fossil fuels to meet its energy needs, which makes the country vulnerable to price volatility and supply disruptions.

Renewable energy sources such as solar, wind, and hydropower can provide a sustainable source of energy and reduce India's dependence on imported fossil fuels, creating vast renewable energy business ideas for entrepreneurs. Moreover, renewable energy can help reduce greenhouse gas emissions and mitigate the impact of climate change, which is a critical challenge faced by the country.

Another critical aspect that makes the renewable energy sector attractive for entrepreneurs in India is the government's supportive policies and incentives. The government has implemented various policies and schemes to promote renewable energy development in the country, such as the National Solar Mission, Renewable Purchase Obligation, and the **Green Energy Corridor**.

Additionally, the government offers various financial incentives such as subsidies, tax exemptions, and low-interest loans to support renewable energy projects. These policies and incentives create a favorable business environment for entrepreneurs to invest in the renewable energy sector

India is making great strides towards becoming a leader in the global shift towards **renewable energy**. In 2020, renewable energy accounted for 23.43% of India's total installed power capacity, up from just 5.83% in 2010. This growth has been driven by a number of factors, including government policies and incentives, falling renewable energy costs, and increasing awareness and demand for clean energy.

One of the key drivers of India's renewable energy growth has been government policies and incentives. The government has introduced a number of measures to promote the development of renewable energy, including feed-in tariffs, renewable purchase obligations, and tax incentives to create numerous renewable energy business ideas for entrepreneurs.

Another important factor has been the falling costs of **renewable energy technologies**. In recent years, the cost of solar and wind power has fallen dramatically, making these technologies increasingly competitive with traditional fossil fuel-based power sources. This has helped to drive demand for renewable energy and has encouraged the development of new projects

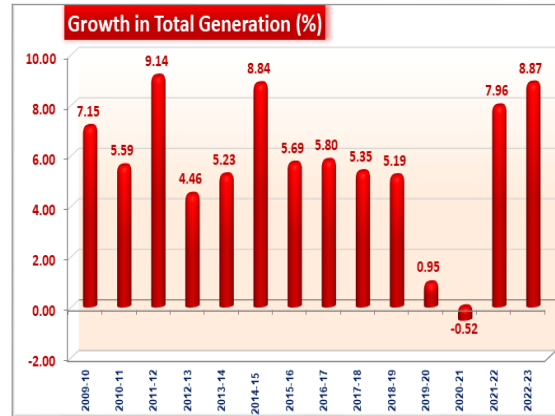


Fig.14 India’s Energy Sector growth in total generation (%) every year 2009-2023

### VIII. FINANCIAL CONSIDERATIONS TO HELP ENSURE UNINTERRUPTED SOLAR POWER GENERATION AT UTILITY

Solar energy will be responsible of an amazing 46% of all additions to the power generating capacity in USA during 2022. Within this figure some, 62% of projects will be linked power storage infrastructure. This is a stunning achievement, but globally solar still needs to conquer a greater portion of the remaining 96% of global capacity. Elsewhere, Germany is fast-tracking its transition to 100% renewable power generation prior to 2035, while for two years running (2020 and 2021), South Australia has been able to momentarily surpass state-wide energy demand with predominantly domestic roof-top solar supply.

In turn, this brings with it serious challenges for managing the stability of national grids due to the intermittency of energy production combined with poor reliability and poor longevity of the associated solar infrastructure. The world is looking more and more to solar for its future energy needs. At utility scale, solar energy facilities have become larger and feature increasingly higher power-generating capacity per hectare, energy storage systems and solar tracking devices – all of which augments project costs. As project costs increase, so too does investor risk. In turn, this significantly increases time to “payback” and still longer before attractive financial returns can be secured.

A challenge to this rosy future, is the **industry-wide issue of under-performance**. This under-performance currently puts sizable investments at risk. Only through the introduction of “Operational Systems Resilience” can this situation be redressed. The latter is based upon avoidance of “Single Point of Failure” and unpredicted technical failure afforded by inverter redundancy coupled with high-granularity monitoring of individual solar panels. Notably, cloud computing, data centers and living organisms could not function effectively without access to « operational systems resilience ». Lower cost Multi-Module Micro-Inverters (MMMI’s) and the Internet of Things (IoT) make this process financially and technically accessible now.

Additional CAPEX comes at a price, but nowhere do these sums approach those associated with more-traditional coal- or gas- fired combined-cycle, nuclear or hydro power generation. Expected project durations for these technologies range respectively from 40-50 years, 40-60 years, and 60-80 years. Here, greater up-front CAPEX does not act as an impediment to project implementation. On the other hand, solar has yet to evolve to a similar way of rationalizing longer-term project finance. The solar sector’s recent growth has been based around the rapid evolution of cheaper, higher-powered, and mostly Chinese solar panels. The sector’s future, however, will demand a leap to similar levels of reliability and durability, i.e., if indeed nations are to take full advantage of the Sun’s inexhaustible energy supply. This will depend upon elimination of underperformance with respect to energy production and its negative impact on associated cashflow projections.

**IX. RECENT ADVANCES OF WIND-SOLAR HYBRID RENEWABLE ENERGY SYSTEMS FOR POWER GENERATION**

A hybrid renewable energy system (HRES) generally consists of two or more renewable energy sources with complementary power generation profiles, such as wind turbines and photovoltaic systems, along with a low-capacity energy storage system to provide non-intermittent power with increased system efficiency and improved stability. The objective of this study is to present a comprehensive review of various wind-solar HRES from the perspectives of power architectures, mathematical modeling, power electronic converter topologies, and design optimization algorithms. Since the intermittency of HRES can be further reduced by including an energy storage system, this paper critically reviews different types of hybrid energy storage systems, focusing on their coupling technologies and highlighting their major advantages and disadvantages. The basic mathematical modeling of photovoltaic and wind turbine power generation systems, as well as the degradation model of batteries and supercapacitors are also reported. Various HRES power converters and control strategies from the state-of-the-art have been discussed. Different types of energy source combinations, modeling, power converter architectures, sizing, and optimization techniques used in the existing HRES are reviewed in this work, which intends to serve as a comprehensive reference for researchers, engineers, and policymakers in this field. This article also discusses the technical challenges associated with HRES as well as the research scope for future advancements. Although considerable accomplishments have been achieved over the past decade on various HRES, such a comprehensive review helps to identify and fulfill the technical gaps to improve the efficiency, stability, and reduce the cost of the power grids.

As per World Energy Outlook 2021 of IEA, the current share of India in global primary energy consumption is 6.1% and is likely to increase to about 9.8% under stated policies scenario by 2050

Owing to technological developments, steady policy support and a vibrant private sector solar power plants are cheaper source of electricity Commercial & Industrial customers pay high power tariffs because they subsidize the low power tariffs of the residential and agricultural sectors.

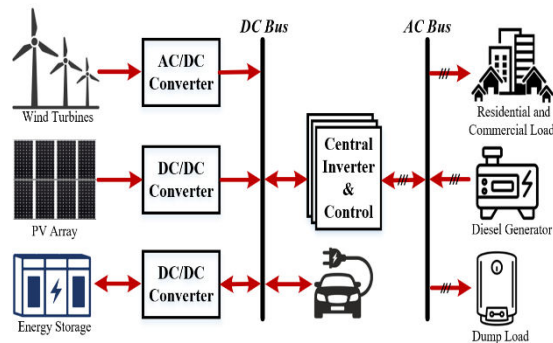


Fig.15. Recent Advances of Wind-Solar Hybrid Renewable Energy Systems for Power Generation

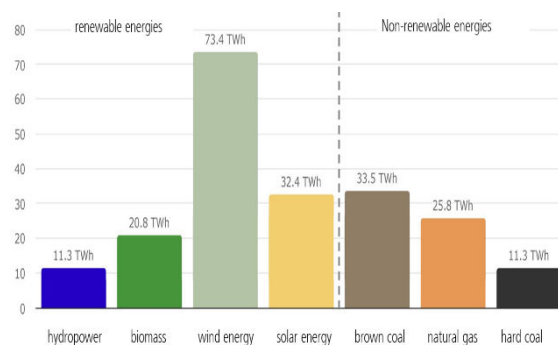


Fig.16. Electricity generation by the renewable energies and non-renewable energies

Net public electricity generation in the first half of 2024. The chart shows the net electricity gen-eration from power plants for the public electricity supply. This is the electricity mix that actually comes out of the socket. Generation from power plants of "companies in the manufacturing, mining and quarrying sectors" i.e., industrial generation for own consumption, is not included in this graph.

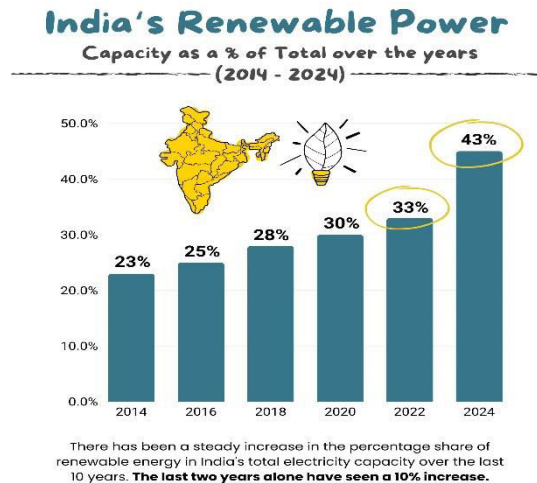


Fig.17. India's Renewable Energy Sector growth in total generation (%) every year 2014 - 2024

## X. REGULATION

### 10.1 Government Lead Initiatives:

- In November 2021, at the Cop-26 Summit in Glasgow, India set ambitious targets to produce 50% of its electricity from renewable sources and install 500 GW of renewable energy capacity by 2030.
- Ministry of Power (Mop), Government of India (GoI) notified the Electricity (Promoting Renewable Energy Through Green Energy Open Access) Rules, 2022 to promote the Green Energy open access across India. This will reduce the diversification of practices related to open access in the states.
- Waivers of open access charges and banking facility offered by multiple state electricity regulators gives incentive to Commercial and Industrial customers to move to Solar Energy.

### 10.2 Implementation:

- In the Union Budget 2022-23, the allocation for the Solar Energy Corporation of India (SECI), which is currently responsible for the development of the entire renewable energy sector, stood at Rs. 1,000 crores (~US\$ 132 million).
- Investment in renewable energy in India reached a record US\$ 14.5 billion in FY22, an increase of 125% over FY21

## XI. ADVANTAGES AND DISADVANTAGES OF DIFFERENT RENEWABLE ENERGY RESOURCES

Renewable energy has multiple advantages over fossil fuels. Here are some of the top benefits of using an alternative energy source:

- Renewable energy won't run out.
- Renewable energy has lower maintenance requirements.
- Renewables save money.
- Renewable energy has numerous environmental benefits.
- Renewables lower reliance on foreign energy sources.
- Renewable energy leads to cleaner water and air.
- Renewable energy creates jobs.

- Renewable energy can cut down on waste.

#### 11.1. Renewable energy won't run out

Renewable energy technologies use resources straight from the environment to generate power. These energy sources include sunshine, wind, tides, and biomass. Renewable resources won't run out, which cannot be said for many types of fossil fuels – as we use fossil fuel resources, they will be increasingly difficult to obtain, likely driving up both the cost and environmental impact of extraction.

#### 11.2. Maintenance requirements are lower for renewable energy

Renewable energy systems usually require less overall maintenance than generators that use traditional fuel sources. This is because generating technology like solar panels and wind turbines either have few or no moving parts and don't rely on flammable, combustible fuel sources to operate. Fewer maintenance requirements translate to more time and money saved.

#### 11.3. Renewables save money

Using renewable energy can help you save money long term. Not only will you save on maintenance costs but also on operating costs. You don't have to pay to refuel when you're using a technology that generates power from the sun, wind, steam, or natural processes. The amount of money you will save using renewable energy can vary depending on several factors, including the technology itself. In most cases, transitioning to renewable energy means anywhere from hundreds to thousands of dollars in savings—find out how much you can save by switching to solar energy.

#### 11.4. Renewable energy has numerous environmental benefits

Renewable energy generation sources lead to lower greenhouse gas emissions than traditional fuel sources like natural gas. This means a smaller carbon footprint and an overall positive impact on the natural environment. During the combustion process, fossil fuels emit high amounts of greenhouse gases, which have been proven to exacerbate climate change, which in turn causes rising global temperatures and higher frequencies of extreme weather events.

The use of fossil fuels emits greenhouse gases and other harmful pollutants that lead to respiratory and cardiac health issues. With renewable energy, you're helping decrease these pollutants' prevalence and contributing to a healthier atmosphere.

#### 11.5. Renewables lower reliance on foreign energy sources

With renewable energy technologies, you can produce energy locally. The higher the amount of our energy use is renewable, the less we'll rely on imported energy, and the more we'll contribute to U.S. energy independence. Renewable energy sources can help us minimize the geo-political risks associated with fossil fuels, from trade disputes to political instability to pricing wars, which are often rooted in access to oil.

#### 11.6. Renewable energy leads to cleaner water and air

When you burn fossil fuels to generate electricity, it contaminates the air and water we use. For example, coal power stations release high volumes of carbon dioxide, nitrous oxide, and harmful toxins like mercury, lead, and sulfur dioxide. Health problems from ingesting these elements can be dangerous and even fatal. Investing in renewable energy is a great way to work against these risks, as renewables have a far lower negative impact on our air and water.

The use of fossil fuels emits greenhouse gases and other harmful pollutants that lead to respiratory and cardiac health issues. With renewable energy, you're helping decrease these pollutants' prevalence and contributing to a healthier environment.

#### 11.7. Renewable energy can help solve our waste problem

Specifically, biomass energy can offer a significant benefit in this way. Biomass generators consume used organic products like vegetable oil, corn and soybean byproducts, and even algae to generate energy. Because of this, using biomass as an energy source can reduce the amount of waste that goes into landfills, which helps cut down on carbon emissions and environmental contamination.

## XII. DISADVANTAGES OF RENEWABLE ENERGY

Renewable energy has many benefits, but it's not always sunny when it comes to renewable energy. Here are some cons of renewable energy when compared to traditional fuel sources:

- Renewable energy has high upfront costs.
- Renewable energy is intermittent.
- Renewables have storage capabilities.
- Renewable energy sources have geographic limitations.
- Renewables aren't always 100% carbon-free.

### 12.1. Higher upfront cost

While you can save money using renewable energy, the technologies are typically more expensive upfront than traditional energy generators. To combat this, financial incentives such as tax credits and rebates are available to help alleviate your initial costs of renewable technology.

### 12.2. Intermittency

Though renewable energy resources are available around the world, many of these resources aren't available 24/7, year-round. Some days may be windier than others, the sun doesn't shine at night, and droughts may occur for periods. Unpredictable weather events can disrupt these technologies, and the amount of energy we can get from renewable power sources can be inconsistent. Fossil fuels are not intermittent, and power plants can be turned on or off at any time to provide an energy supply. Wondering if you should make the switch to renewables? Find out if an energy source like solar power is a good fit for you.

### 12.3. Storage capabilities

Because of the intermittency of some renewable energy sources, there's a high need for energy storage. Storage technologies are available but can be expensive, especially for large-scale renewable energy plants. It's worth noting that energy storage capacity is growing as the technology progresses, and batteries are becoming more affordable as time passes.

### 12.4. Not 100% carbon-free

Although solar panels and other forms of renewable energy drastically reduce carbon emissions, these resources aren't always completely clean. The manufacturing, transportation, and installation of renewable energy, like wind turbines, can create a carbon footprint since they're usually produced in factories powered by fossil fuels—not to mention the diesel and gasoline needed to fuel the transport trucks. As the U.S. becomes more and more electrified – from solar panels on factories to electric transport trucks – carbon emissions associated with solar will continue to decrease.

### 12.5. Supply chain constraints

Renewables must have an effective distribution network created to transfer the energy where it's needed on a large scale. These networks need non-renewable fuels to be generated, which offsets the benefits of renewable energy for a bit until it's paid back. Additionally, politics can play a factor in installing renewable energy if it's not a priority among local governments.

The module highlights the dismal increase in renewable energy uptake in the energy-consuming sectors. In 2021, renewable energy rose to 15.9% in building (up 0.4%), and to 16.5% in agriculture (up 1%), while industry stagnated at 16.8%. The share of renewables in transport decreased from 4.1% in 2020 to 3.9% in 2021 due to increased demand being met by fossil fuels.

By the end of 2023, only 13 countries including Greece, Portugal, Spain, Ireland, United Kingdom, Italy, United States of America, Egypt, China, Vietnam, France, Germany and India, had implemented **renewable energy policies** across all end-use sectors—buildings, industry, transport, and agriculture.



Promoting Renewable Energy Sources and Sustainability

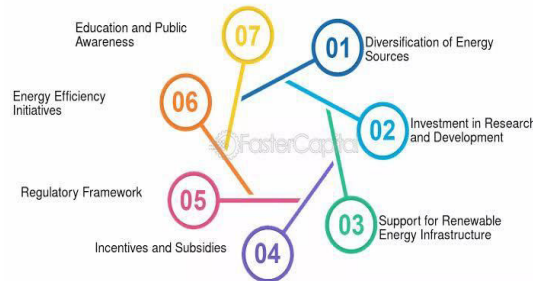


Fig.18. Promoting Renewable energy Sources Sustainability

Similarly, in the **agriculture sector** only 4 countries (Bangladesh, India, Republic of Korea and Malta) and the EU, have renewable energy targets, despite the myriad benefits of integrating renewables with agricultural practices. Efforts to integrate renewables into **aviation, rail, and shipping** are gaining momentum, but continue to face political hurdles. By 2023, only 10 countries had announced renewable energy policies for these sectors. The report highlights how energy-efficient solar-powered cold storage systems in Kenya have proven affordable and reliable for small-scale farmers, leading to an increase in incomes of up to 40%. The **buildings sector** brought some hope with investment in energy efficiency rising by 14% in 2022 to reach USD 285 billion.

### XIII. DIVE INTO THE RENEWABLES 2024 GLOBAL STATUS REPORT

Since 2023, REN21 has been releasing the Renewables Global Status Report (GSR) as a collection of modules to rigorously cover the energy system from its different elements, including demand, supply, systems and infrastructure, and economic and social value creation.

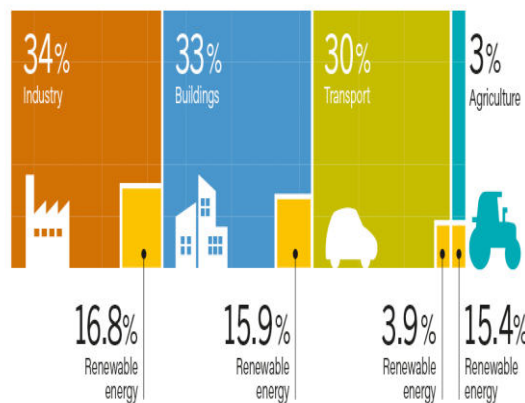


Fig.19. Renewables 2024 Global Status Report -Energy Demand Module

This Energy Demand Module follows the first module of the GSR 2024 series – the Global Overview – launched in April, which provides the status picture of renewables in the wider energy system and in the context of global challenges such as climate change, development goals, and the geopolitical landscape.

The upcoming Modules will explore different aspects of the energy system, including supply; systems and infrastructure; and economic and social value creation.

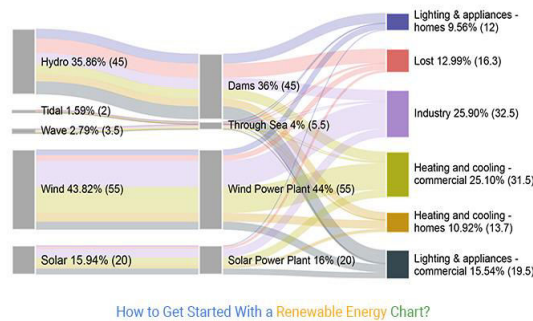


Fig.20

Global warming, climate change, and renewable energies dominate discourses in forums, such as the World Economic Forum in Davos and the UN.

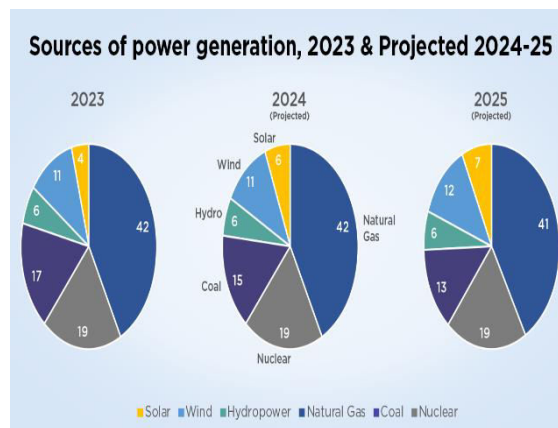


Fig.21. Sources of power generation, 2023 & projected 2024-25

Integration is power quality, reliability, energy conversion cost and power system efficiency. Research and development regarding these issues are underway and several methodologies and algorithms have been proposed in order to meet these challenges and making power grid transition towards smart one in an effective manner. The above fig. gives the brief classification of challenges faced in integration. After the description of the different renewable energy sources, it should be noted that each source of renewable energy has its advantages and disadvantages as summarized by above fig.

#### XIV. CONCLUSION

Energy is a requirement in our everyday life as a way of improving human development leading to economic growth and productivity. The return-to-renewables will help mitigate climate change is an excellent way but needs to be sustainable in order to ensure a sustainable future for generations to meet their energy needs. Knowledge regarding the interrelations between sustainable development and renewable energy in particular is still limited.

The aim of the paper was to ascertain if renewable energy sources were sustainable and how a shift from fossil fuel-based energy sources to renewable energy sources would help reduce climate change and its impact. Qualitative research was employed by reviewing papers in the scope of the study.

Even though, the complete lifecycle of renewable energy sources has no net emissions which will help limit future global greenhouse gas emissions. Nevertheless, the cost, price, political environment and market conditions have become barriers preventing developing, least developed and developed countries to fully utilize its potentials.

In this way, a creation of global opportunity through international cooperation that supports least developed and developing countries towards the accessibility of renewable energy, energy efficiency, clean energy technology and research and energy infrastructure investment will reduce the cost of renewable energy, eliminate barriers to energy efficiency (high discount rate) and promote new potentials towards climate change mitigation.

#### REFERENCES

1. REN21, Renewables 2013: global status report, ([www.ren21.net](http://www.ren21.net)), [accessed on 25/6/2013].
2. Kaygusuz K. Wind power for a clean and sustainable energy future. *Energy Sources Part B* 2009;4(1):122–32.
3. Islam MR, Mekhilef S, Saidur R. Progress and recent trends of wind energy technology. *Renewable Sustainable Energy Rev* 2013; 21:456–68.
4. Eltamaly AM. Design and implementation of wind energy system in Saudi Arabia. *Renewable Energy* 2013; 60:42–52.
5. (23 May 2012). "Artificial leaf faces economic hurdle: Nature News & Comment". *Nature News*. *Nature.com*. doi:10.1038/nature.2012.10703. S2CID 211729746. Archived from the original on 1 December 2012. Retrieved 7 November 2012.
6. [10:57 PM, 11/12/2024] Srinu: Renewable Energy Market Update - May 2022 – Analysis". IEA. 11 May 2022. p. 5. Retrieved 27 June 2022
7. Nguyen TH, Prinz A, Friis T, Nossun R, Tyapin I. A framework for data integration of offshore wind farms. *Renewable Energy* 2013; 60:150–61.
8. Deploying renewables: best and future policy practice, 2011, ([www.iea.org](http://www.iea.org)), [accessed on 27/6/2013].
9. Doner J. Barriers to adoption of renewable energy technology. Illinois State University. Institute for Regulatory Policy Studies; 2007 (May).
10. Wiuff A, Sandholt K, Marcus-Møller C. Renewable energy technology deployment: barriers, challenges and opportunities, EA energy analyses for the IEA RETD implementing agreement; May 2006.
11. Bose BK. Global energy scenario and impact of power electronics in 21st century. *IEEE Trans Ind Electron* 2013;60(7):2638–51.
12. Bose BK. Global warming: energy, environmental pollution, and the impact of power electronics. *IEEE Ind Electron Mag* 2010;4(1):6–17.
13. Chakraborty A. Advancements in power electronics and drives in interface with growing renewable energy resources. *Renewable Sustainable Energy Rev* 2011; 15:1816–27.
14. Available: <http://www.cnie.org/nle/eng-29.html>, 1997.
15. A. K. N. Reddy, R. H. Williams, and T. B. Johansson, *Energy After Rio: Prospects and Challenges*. New York: United Nations Development Programme, 1997.
16. T. B. Johansson et al., *Renewable Energy: Sources for Fuels and Electricity*. Washington, DC: Island Press, 1996.
17. "Renewable Energy Technology Characterizations," Electric Power Research Inst. And U.S. Dept. of Energy, EPRI TR-109 496, 1997.
18. [10:59 PM, 11/12/2024] Srinu: Armaroli, Nicola; Balzani, Vincenzo (2011). "Towards an electricity-powered world". *Energy and Environmental Science*. 4 (9): 3193–3222. doi:10.1039/c1ee01249e. ISSN 1754-5692.
19. [10:59 PM, 11/12/2024] Srinu: "Global renewable energy trends". Deloitte Insights. Archived from the original on 29 January 2019. Retrieved 28 January 2019.
20. [11:00 PM, 11/12/2024] Srinu: "2023 Levelized Cost of Energy+". [www.lazard.com](http://www.lazard.com). Retrieved 10 June 2024.
21. [11:00 PM, 11/12/2024] Srinu: IEA (2020). *Renewables 2020 Analysis and forecast to 2025 (Report)*. p. 12. Archived from the original on 26 April 2021. Retrieved 27 April 2021.
22. [11:01 PM, 11/12/2024] Srinu: "Renewables 2022". *Global Status Report (renewable energies)*: 44. 14 June 2019. Retrieved 5 September 2022.
23. "Share of electricity production from renewables". *Our World in Data*. 2023. Retrieved 15 August 2023.
24. Global tracking framework, ([www.worldbank.org/se4all](http://www.worldbank.org/se4all)), [accessed on 24/6/ 2013].
25. "Photovoltaics: The power of choice: The national photovoltaics program plan for 1996–2000," U.S. Dept. of Energy, *PV News*, vol. 20, no. 2, Mar. 2001.

26. "Energy Communities". Nordic Cooperation. Retrieved 31 May 2024.
27. K. Kris Hirst. "The Discovery of Fire". About.com. Archived from the original on 12 January 2013. Retrieved 15 January 2013.
28. "wind energy". The Encyclopedia of Alternative Energy and Sustainable Living. Archived from the original on 26 January 2013. Retrieved 15 January 2013.
29. "Geothermal Energy". faculty.fairfield.edu. Archived from the original on 25 March 2017. Retrieved 17 January 20
30. [9:04 AM, 11/13/2024] Srinu: "Solar Panel Recycling". www.epa.gov. 23 August 2021. Retrieved 2 May 2022.
31. [9:06 AM, 11/13/2024] Srinu: Ince, Matt; Sikorsky, Erin (13 December 2023). "The Uncomfortable Geopolitics of the Clean Energy Transition". Lawfare. Retrieved 10 April 2024.
32. [9:07 AM, 11/13/2024] Srinu: World Energy Transitions Outlook: 1.5°C Pathway. Abu Dhabi: International Renewable Energy Agency. 2021. p. 24. ISBN 978-92-9260-334-2.
33. [9:08 AM, 11/13/2024] Srinu: Shepherd, Christian (29 March 2024). "China is all in on green tech. The U.S. and Europe fear unfair competition". The Washington Post. Retrieved 10 April 2024
34. [9:09 AM, 11/13/2024] Srinu: "The transition to clean energy will mint new commodity superpowers". The Economist. ISSN 0013-0613. Retrieved 2 May 2022
35. [9:10 AM, 11/13/2024] Srinu: "The Geopolitics of Renewable Energy". ResearchGate. Archived from the original on 28 July 2020. Retrieved 26 June 2019
36. [9:10 AM, 11/13/2024] Srinu: REN21 Renewables Global Futures Report 2017.
37. [9:11 AM, 11/13/2024] Srinu: "IRENA Membership". /irenamembership. Archived from the original on 6 April 2019. Retrieved 8 April 2019
38. [9:12 AM, 11/13/2024] Srinu: "Share of electricity production from renewables". Our World in Data. Retrieved 20 June 2024.
39. [9:12 AM, 11/13/2024] Srinu: Kabintie, Winnie (5 September 2023). "Africa Climate Summit - opportunities for harnessing renewable energy". The Kenya Forum. Retrieved 5 September 2023
40. [5:01 PM, 11/13/2024] Srinu: IRENA 2024, p. 21. Note: Compound annual growth rate 2014-2023.
41. [5:02 PM, 11/13/2024] Srinu: "Global Electricity Review 2024". Ember. 8 May 2024. Retrieved 8 May 2024.
42. [5:02 PM, 11/13/2024] Srinu: "Global landscape of renewable energy finance 2023" (PDF). International Renewable Energy Agency (IRENA). February 2023. Archived from the original (PDF) on 21 March 2024. Retrieved 21 March 2024.
43. [5:04 PM, 11/13/2024] Srinu: UK, Maria Mellor, WIRED. "Biofuels are meant to clean up flying's carbon crisis. They won't". Wired. ISSN 1059-1028. Retrieved 5 May 2024.



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