

Review of Energy Sources (Renewable and Non-Renewable)

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ABSTRACT

This is a comprehensive review of energy sources, categorized into renewable and non-renewable types, highlighting their characteristics, sources, transformations, and environmental impacts. Renewable energy sources like sun, wind, geothermal, hydro, ocean, and bioenergy are discussed in terms of their sustainability and growing global significance in mitigating climate change. In contrast, non-renewable sources such as fossil fuel like coal, petroleum, natural gas, and nuclear power are examined for their widespread use, high energy density, and associated environmental concerns. The review also explores the advantages and disadvantages of each type of sources and the need for a balanced and sustainable energy strategy. The information aims to promote awareness about energy choices and encourage the transition toward cleaner alternatives.

Keywords: Renewable energy, Non-renewable energy, Fossil fuels, Energy transformation, Sustainability

INTRODUCTION

Energy refers to the capacity to perform work. It cannot be created or destroyed but can only be transformed from one form to another. Human activities involve the conversion of energy between different forms to accomplish tasks. For instance, during walking, the body transforms stored chemical potential energy into mechanical energy—manifesting as kinetic energy when in motion and as potential energy when the body is momentarily at rest. Every action or task requires some form of energy to be carried out.

Renewable energy originates from natural sources that naturally regenerate at a much faster pace than they are used up. In contrast, non-renewable energy sources require millions of years to develop. Resources such as sunlight, wind, water, and land, which exist in abundant and continuous supply on Earth, are classified as renewable. On the other hand, fossil fuels and nuclear materials are examples of non-renewable resources, as their formation takes an extensive geological timescale.

Fossil fuels are formed from the decomposed remains of ancient plants and animals over millions of years. Common examples include natural gas, coal, and crude oil.¹

Nuclear fuel, with uranium being one of the most commonly used types, plays a significant role in global energy production. Nuclear energy contributes approximately 6% to the world's total energy supply and accounts for about 10% of global electricity generation. Types of renewable energy.² With global electricity demand growing and climate goals tightening, low-carbon, reliable energy solutions are urgently required. Nuclear power currently generates nearly 10% of global electricity, positioning it as the second-largest source of low-emission power after hydropower. Nuclear output reached 2,602 TWh, roughly 9% of total global electricity, maintaining a high capacity factor (~81.5%). Currently 64 reactors are under construction across 15 countries, primarily in Asia and China. Future plan on Capacity grows from 416 GW (2023) to 647 GW by 2050.³

Solar energy refers to the power obtained from the Sun. Using technologies such as photovoltaic cells and reflective mirrors, this energy can be collected and converted into heat or electricity. Among all energy sources, solar is the most plentiful and can even be utilized during overcast conditions. The Earth receives solar radiation at a rate nearly 10,000 times higher than the current global energy demand, making it one of the most promising forms of renewable energy.⁴

Over the past ten years, the production cost of solar panels has significantly decreased, making solar power one of the most economical sources of electricity.⁵ These panels typically have a lifespan of around 30 years and are available in various designs and colors based on the materials used in their construction.

Wind energy harnesses the movement of air to produce mechanical power, which is used to spin the blades of a wind turbine. This rotational motion drives a rotor connected to an electric generator, converting mechanical energy into electrical energy.⁶ These systems can operate both on land (onshore) and over bodies of water (offshore). Wind turbines utilize the kinetic energy of air currents, making wind power a clean and renewable source of electricity.

Although high wind speeds are found in various regions across the globe, the most suitable areas for wind energy generation are often situated in remote or hard-to-access locations. Offshore wind farms, in particular, present significant opportunities for large-scale power production.

Geothermal energy refers to the heat naturally stored beneath the Earth's surface.⁶ This form of energy is commonly used in industrial processes, such as heating water and generating power. It is accessed by drilling wells or using other extraction methods to tap into underground heat. There are two main types of geothermal reservoirs: hydrothermal systems, which naturally possess adequate heat and permeability, and enhanced geothermal systems, where stimulation techniques are used to improve heat extraction. The high-temperature fluids brought to the surface are utilized to produce electricity. Hydrothermal systems have proven to be dependable and have been in operation for over a century.

Hydropower refers to the energy harnessed from the movement of water. This form of energy is captured from natural processes such as tides and the flow of water from higher to lower elevations, which is commonly referred to as tidal energy. Similarly, the motion of ocean waves, known as wave energy, can also be utilized to generate electricity.

Electricity from hydropower is commonly produced using stored water in reservoirs or through run-of-river systems. In addition to power generation, hydropower reservoirs serve various purposes, including supplying drinking water, supporting irrigation, managing floods and droughts, facilitating navigation, and maintaining water levels.

Currently, hydropower stands as the most widely used source of renewable electricity worldwide. However, its reliability is closely linked to consistent rainfall, and it may be affected by climate-related changes such as droughts or disruptions in local ecosystems. Moreover, the construction of hydropower infrastructure can negatively affect the surrounding environment.

Due to these concerns, small-scale hydropower is often viewed as a more sustainable and eco-friendly solution, particularly beneficial for rural or remote communities.

Ocean energy refers to the mechanical (kinetic) and thermal energy stored in seawater, which can be harnessed from tides, waves, and ocean currents to produce electricity or thermal power using specialized technologies. Although still in the developmental phase, various experimental technologies and prototypes—such as wave and tidal current devices—are currently being tested to explore their feasibility and efficiency.

Bioenergy is derived from biomass, which consists of organic materials like plant residues and animal waste. These materials store chemical energy that can be released as heat when burned, which is then used to produce electricity or power machinery. Common biomass sources include wood, charcoal, crop residues, animal dung, and organic waste, especially in rural areas where such resources are used for heating, cooking, and lighting.

Modern bioenergy systems make use of dedicated energy crops, agricultural and forestry residues, and biodegradable waste. While the combustion of biomass does emit greenhouse gases, it typically results in lower emissions compared to fossil fuels like coal, oil, or natural gas. Nevertheless, large-scale use of bioenergy must be approached cautiously, as it can lead to deforestation, biodiversity loss, and undesirable changes in land use when forests are cleared to make room for bioenergy plantations.

Types of Non-renewable energy -

Coal is a sedimentary rock that appears in shades of black or brown and is primarily used as a fuel source. It generates energy through combustion. The classification of coal is determined by the extent of carbonization it has undergone—a process in which ancient plant material is thermally decomposed under high pressure and heat to form carbon-rich substances.

This transformation usually takes place in oxygen-poor (anaerobic) environments. It is estimated that roughly one foot (about 0.3 meters) of coal is produced from around ten feet (three meters) of compacted plant matter.

Coal is categorized into different grades based on how extensively it has carbonized. Peat, considered the lowest grade, undergoes minimal carbonization and serves as an essential fuel in countries like Ireland, Scotland, and Finland. Anthracite, the highest quality coal, is formed in regions with intense geological activity, such as mountain-building zones. A notable example of its abundance is in the Appalachian region of the eastern United States.

Coal is obtained from the Earth and utilized as a fuel to generate energy. It is mined using two main techniques: underground mining and surface mining. When coal deposits lie deep within the Earth—typically around 300 meters or more—underground mining is the preferred method. On the other hand, if the coal seams are located near the surface, surface mining is carried out. In this method, layers of soil and vegetation are cleared to expose the coal, which often leads to severe environmental degradation, including the destruction of local ecosystems.

In the United States, coal is responsible for supplying approximately 20% of the nation's electricity. It powers a wide range of household appliances, including lighting, refrigerators, and dishwashers. In addition to energy, coal combustion produces byproducts that are put to use in manufacturing materials such as cement, road surfaces, plastics, and various industrial goods.

Petroleum, also known as crude oil or simply oil, is a liquid form of fossil fuel found trapped within layers of underground rock. In some locations, it naturally seeps to the surface, but the majority remains buried deep beneath the Earth's crust, including under the ocean floor. To extract it, companies use drilling rigs that operate continuously throughout the year. Many oil fields can remain productive for several decades, often extending beyond 30 years. When located offshore, oil extraction involves the construction of large platforms to support deep-sea drilling operations.

Once brought to the surface, crude oil must undergo refining to separate and remove various chemical components. Roughly half of all refined petroleum is converted into gasoline, while the remaining portions are transformed into a wide array of products. These include solid items such as plastic piping, footwear, crayons, roofing materials, and vitamin capsules, as well as liquids like rubbing alcohol and nail polish.

Natural gas is a fossil fuel in gaseous form, stored in underground reservoirs. It is primarily composed of methane—a colorless, odorless gas that often has a sulfur-like smell due to added odorants for leak detection. Methane is also naturally produced from decaying organic matter in places like landfills. The volume of natural gas stored beneath the Earth's surface is immense, measured in millions to trillions of cubic meters. These gas reserves are typically located a few hundred meters deep within extensive rock formations.

To access these underground deposits, energy companies drill wells and use pipelines to extract the gas. One common method of extraction is called *hydraulic fracturing*, or *fracking*, which involves injecting high-pressure water into rock layers to fracture them and release the trapped gas. In some cases, acids are introduced to dissolve tougher rocks, or materials like sand and glass particles are added to keep the fractures open and allow gas to flow more freely.

Natural gas is widely utilized for domestic purposes such as heating and cooking. It also serves as a fuel for generating electricity, which powers various household appliances including lights, televisions, air conditioners, and kitchen equipment.

Natural gas can be converted into its liquid form, known as liquefied natural gas (LNG), which is more compact and easier to store and transport than its gaseous counterpart. LNG is considered a cleaner alternative to many other fossil fuels, emitting fewer pollutants. Its versatility allows it to be used in various sectors and, in some cases, it can even replace gasoline as a fuel source.

Nuclear Power

Nuclear energy represents another form of non-renewable power, as the materials used in its generation—primarily uranium—are finite. This energy originates from the dense core of atoms, where a tremendous amount of force is stored. Through a process known as nuclear fission, the nucleus of an atom is split, releasing a substantial amount of energy. Nuclear power plants are highly sophisticated facilities that harness this reaction to produce electricity.

Uranium, especially the rare isotope U-235, is the most frequently used fuel in nuclear reactors, although uranium itself is relatively abundant in the Earth's crust. Despite its non-renewable nature, nuclear energy contributes significantly to global electricity generation. One of its key advantages is that it does not emit greenhouse gases during operation, making it cleaner than fossil fuels in terms of air pollution. Moreover, nuclear plants can be built in both urban and remote areas.

However, developing nuclear energy systems involves considerable technical challenges. Designing and managing these power plants requires specialized expertise and infrastructure, which may not be readily available in all regions. A major concern is the generation of radioactive waste, which remains hazardous for long periods. Exposure to such waste can lead to serious health issues, including cancer, blood disorders, and bone damage.⁸



Fig- Environmental difference between Renewable and Non-renewable energy resources.⁸

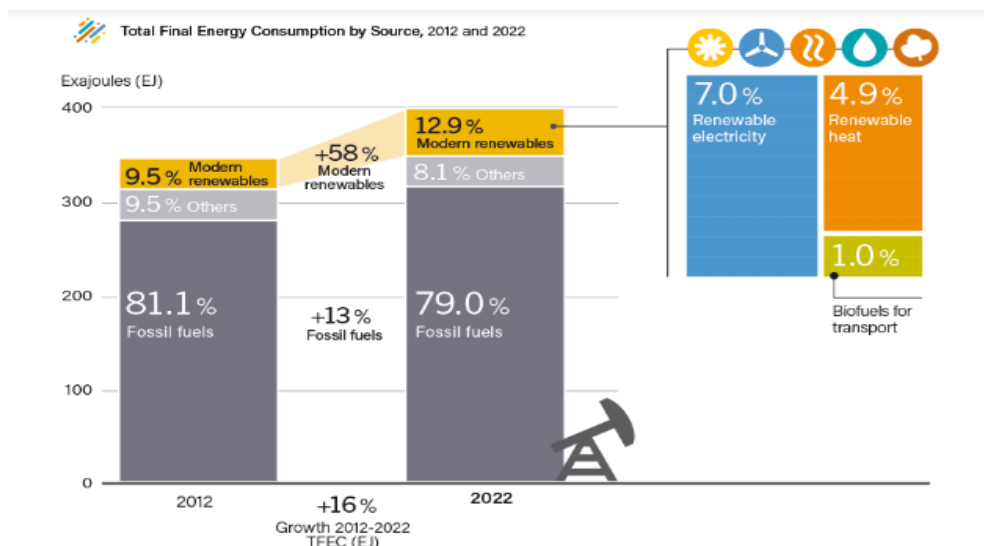


Fig – Total final energy consumption by source in 2012 and 2022.⁹

Advantages and Disadvantage of Renewable Energy

Following are the advantages and disadvantages of Renewable energy.

Advantages:

- The most important advantage of using renewable energy is that they emit minimum greenhouse gas. Hence can reduce air pollution and climate change process.
- Using renewable energy which is more environmentally friendly energy sources can save people from for asthma and emissions-related respiratory illnesses and hence save the cost in healthcare.
- We can conserve the non renewable energy resources.
- Renewable energy systems, once installed, often have low operational costs and provide free energy from natural resources.

Disadvantages:

- Renewable energy resources, Solar and wind energy are weather-dependent, location-dependent and may not produce power consistently without storage systems.
- High Installation costs for renewable energy systems than traditional fossil fuel-based systems.
- Large-scale projects like wind farms and hydropower plants requires huge land for installation and so it has impact ecosystems, wildlife, and local communities.
- Solar panels and wind turbine blades may pose challenges for recycling and safe disposal at the end of their life cycle.

Advantages and Disadvantage of Non - Renewable Energy

Advantages of Non-Renewable Energy:

- Fossil fuels contain a large amount of energy per unit of mass or volume.
- Small amounts can produce large quantities of electricity or heat.
- Non-renewable sources provide a constant and stable energy output (unlike solar or wind, which are weather-dependent).
- Extensive infrastructure and technologies for extraction, refining, transport, and distribution are already in place.
- Easy to scale up quickly to meet large energy demands.

Disadvantages of Non-Renewable Energy:

- Burning fossil fuels releases carbon dioxide (CO₂), sulfur dioxide (SO₂), nitrogen oxides (NO_x), and particulate matter.
- Leads to air pollution, acid rain, and global warming.
- Major contributor to climate change due to high CO₂ emissions.
- Fossil fuels account for the majority of global greenhouse gas emissions.
- Non-renewables take millions of years to form and will eventually run out.
- Oil spills, coal mine explosions, and nuclear accidents (e.g., Chernobyl, Fukushima) can cause catastrophic damage to ecosystems and human health.
- As easy-to-reach reserves are depleted, extraction becomes more costly and environmentally damaging (e.g., deep-sea drilling, tar sands).

In various regions worldwide, renewable energy options—especially solar and wind—have become more economical compared to conventional fossil fuels. The levelised cost of electricity (**LCOE**) for these clean energy sources has been steadily decreasing. According to 2023 data, the global weighted average LCOE for newly deployed renewable projects showed significant reductions: solar photovoltaic (PV) costs dropped by 12%, hydropower by 7%, offshore wind by 7%, onshore wind by 3%, and concentrating solar power (CSP) by 4%. Meanwhile, substantial subsidies from governments and financial sectors continue to artificially portray fossil fuels as inexpensive and readily available.

The year 2023 marked a record peak in renewable energy expansion, with clean energy sources and supportive technologies contributing approximately 7% to the global GDP increase during that period. Across the entire renewable energy value chain—from raw material extraction and processing to equipment production, project execution, operations, and energy distribution—there are significant prospects for local economic growth and employment generation.

By 2023, employment within the renewable energy sector rose to an unprecedented 16.2 million direct and indirect jobs, up from 13.7 million in 2022. The potential for job creation in renewables is projected to substantially surpass the anticipated employment reductions in the fossil fuel sector. Furthermore, nearly 70% of the workforce in the oil and gas industries possesses skillsets that are transferable to roles within the clean energy transition.⁹

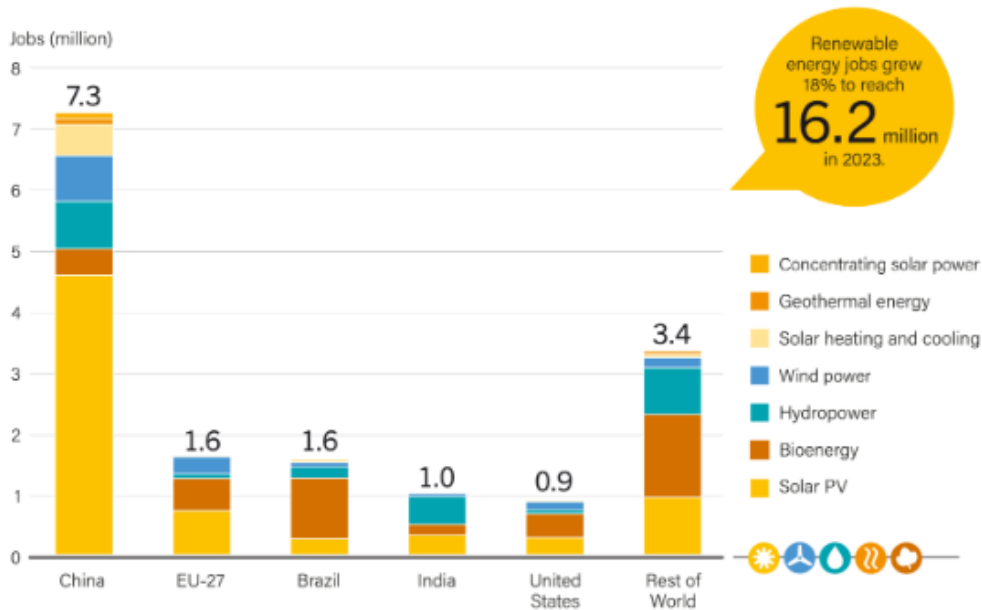


Fig- Global Renewable Energy Employment, by technology and Region, 2023.⁹

CONCLUSION

Energy plays a pivotal role in sustaining life and powering human activities. In this chapter, we explored the various sources of energy—both renewable and non-renewable—and examined their forms, uses, advantages, and limitations. Renewable energy sources like solar, wind, geothermal, hydropower, ocean energy, and bioenergy offer sustainable alternatives that help reduce environmental pollution and greenhouse gas emissions. However, they come with challenges such as weather dependency and higher initial costs.

Non-renewable energy sources, including coal, petroleum, natural gas, and nuclear energy, have long driven industrial growth due to their high energy density and reliable supply. Yet, their continued use poses serious environmental and health risks, including air pollution, global warming, and ecological degradation.

A balanced and informed approach to energy production and consumption—emphasizing cleaner, renewable alternatives while responsibly managing non-renewable resources—is essential for ensuring long-term energy security and environmental sustainability. As future energy needs grow, innovation and sustainable practices must guide our transition towards a cleaner and greener energy future.

A forward-looking energy strategy must prioritize the rapid adoption of renewable energy while responsibly managing the remaining non-renewable reserves. Policymakers, industries, and communities must collaborate to expand renewable infrastructure, invest in energy storage technologies, and develop clean innovations like hydrogen energy and small modular reactors. By integrating sustainability principles with technological progress, society can secure long-term energy availability, minimize environmental impacts, and contribute to global climate goals.

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