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Oil and Renewable Energies: A Review

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Abstract

Energy plays a critical role in driving the development and sustainability of modern societies, serving as a foundational component in fulfilling essential human needs such as heating, transportation, cooking, and powering industrial and domestic activities. Although renewable energy sources—such as solar, wind, hydro, and biomass—are gaining traction due to their environmental benefits and long-term sustainability, non-renewable sources like oil continue to dominate the global energy system. This study aims to conduct a comparative analysis of renewable energy and oil, examining their respective characteristics, advantages, and limitations. The analysis highlights that while renewable sources are cleaner and replenishable on a human timescale, oil remains a dominant energy source due to its high energy density, ease of storage and transport, and integral role in the global economy. However, the environmental drawbacks and finite nature of oil underscore the urgency of transitioning toward more sustainable alternatives. The findings underscore the necessity of a gradual but deliberate shift toward renewable energy to reduce greenhouse gas emissions, combat climate change, and ensure long-term energy security. This study contributes to the ongoing discourse on sustainable energy transitions and offers insights into the challenges and opportunities associated with reducing global dependence on fossil fuels.

Keywords: Renewable Energy; Fossil Fuels; Energy Transition; Sustainability; Climate Change Mitigation

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Introduction

Energy is indispensable for the functioning of societies, both to meet basic human needs such as cooking, heating, health, and education and to support economic and social development, particularly in agriculture, industry, and services (Malik D., 2023). According to Daniel Spreng et al. (1994), energy plays a fundamental role in the interactions between humans and their natural environment. Since the beginning of human existence, daily life has been closely dependent on energy needs (Rania Ben Hamida, 2014). Energy is also a complex concept to teach, regardless of the educational level. This difficulty arises largely from the nature of the concept itself, which is abstract, manifests in multiple forms, and is difficult to define precisely (Muriel G. & Arnaud M., 2014). Energy is a physical quantity that characterizes the state of a system and its ability to evolve. It is conserved throughout all transformations (Travers, C. & Clause, O., 2002). Energy is a polymorphic concept, whose understanding depends on disciplinary context, the required level of abstraction, and the representations employed (Lemeignan, G. & Weil-Barais, A., 1993). The International Union of Pure and Applied Physics (IUPAP) also describes energy as a central concept that connects seemingly different phenomena through a unified mathematical formulation (IUPAP, 2010). I. Bazarov (1989) defines energy as a state function that serves as a common measure for the simplest forms of motion of structural elements of matter as they transform into one another.

Energy sources can be classified as renewable or non-renewable (Madi Belkacem, 2022). Renewable energies are those that are replenished within a short period, such as solar energy, hydropower, and biogas. Non-renewable energies, on the other hand, take much longer to form and are therefore called fossil fuels. Among non-renewable energy sources are petroleum, natural gas, and coal. To meet its energy needs, humanity relies on various natural resources such as water, air, soil, and sunlight. Etymologically, the word petroleum comes from the Latin petra (rock) and oleum (oil), meaning "rock oil" (Harche, 2017). Refiners define petroleum as a mixture of liquid hydrocarbons containing dissolved gases and solids. A hydrocarbon is an organic compound composed solely of carbon (C) and hydrogen (H) (IUPAC, 1997), with the general formula C_xH_y. Given the environmental impacts of petroleum, the current trend is to shift toward new and renewable energy sources. In this study, we aim to highlight the benefits of petroleum that renewable energies may not be able to fully replace.

Forms of Energies

Non-renewable energies

Non-renewable energies are limited resources that form very slowly and are depleted much faster than they can be renewed. They are derived mainly from fossil hydrocarbons such as petroleum, natural gas, coal, and certain oils. Non-renewable energy sources can be classified into two main categories:

1. Fossil energies

Coal, natural gas, and petroleum are fossil fuels that were formed from the remains of ancient plants and microorganisms buried and subjected to heat and pressure over millions of years. These resources have played a vital role in industrial development, providing most of the world's energy for electricity generation, transportation, and manufacturing. However, their regeneration process is extremely slow compared to the speed at which humans consume them, creating a significant risk of depletion in the future. Moreover, the combustion of fossil fuels releases large quantities of carbon dioxide and other greenhouse gases, contributing to global warming and environmental degradation. As reserves become harder to access and their extraction more damaging to ecosystems, the need for sustainable alternatives becomes increasingly urgent. Transitioning toward renewable energy sources such as solar, wind, and hydro power is therefore essential to ensure long-term energy security and protect the planet's ecological balance (Intergovernmental Panel on Climate Change, 2021 ; CEA, 2025 ; EIA, 2025 ; WNA,2025).

2. Nuclear energy

This form of energy, known as nuclear energy, is generated either through the fission of heavy atomic nuclei, such as uranium or plutonium, or through the fusion of light atomic nuclei, such as hydrogen. In nuclear fission, the nucleus of a heavy atom is split into smaller fragments, releasing a large amount of energy in the form of heat. This heat is then used to produce steam that drives turbines and generates electricity. In contrast, nuclear fusion occurs when two light nuclei combine to form a heavier one, releasing even more energy. Fusion is the process that powers the sun and other stars, and it represents a potential future source of almost limitless clean energy. However, despite its promise, controlled fusion remains technologically challenging to achieve on Earth. Nuclear energy, while efficient and low in carbon emissions, raises concerns about

radioactive waste management, safety risks, and the potential for nuclear accidents (CEA, 2025 ; EIA, 2025 ; WNA,2025).

Renewable energies

Renewable energies, also known as green energies, are energy sources that naturally regenerate over a short period within a human lifetime. They originate from recurring natural phenomena, often linked to celestial bodies such as the Sun and the Moon (International Energy Agency, 2023). The main sources include solar energy, produced by capturing sunlight through photovoltaic or thermal systems; wind energy, generated from the movement of air masses ; and hydropower, derived from the kinetic energy of flowing water (United Nations Environment Programme, 2022). Other sources, such as biomass and geothermal energy, utilize organic matter and Earth's internal heat, respectively (World Energy Council, 2021). Renewable energies are considered sustainable because they emit little to no greenhouse gases and contribute to reducing dependence on fossil fuels. Their development is essential to achieving a low-carbon future and mitigating the effects of climate change (IEA, 2023 ; UNEP, 2022). They mainly derive from the following sources :

1. From the sun

Solar energy manifests itself in multiple natural processes, including radiation, the water cycle, wind formation, and photosynthesis. As the primary source of energy on Earth, the Sun drives climate systems and sustains life by providing the energy required for plant growth and ecosystem functioning (International Energy Agency, 2023 ; United Nations Environment Programme, 2022). Solar radiation is directly harnessed through photovoltaic panels and solar thermal systems to generate electricity and heat. Indirectly, solar energy contributes to wind energy, as differences in temperature cause air movement, and to hydropower, by fueling the water cycle through evaporation and precipitation (IEA, 2023). Additionally, photosynthesis in plants converts sunlight into chemical energy, forming the basis of the food chain and supporting biomass energy (UNEP, 2022). Exploiting solar energy is crucial for reducing greenhouse gas emissions and transitioning toward a sustainable, low-carbon energy future.

2. Geothermal energy

Geothermal energy originates from the natural radioactivity of elements such as uranium, thorium, and plutonium, which generate heat within the Earth's crust. This energy is harnessed by tapping underground reservoirs of hot water and steam to produce electricity and provide heating for residential, commercial, and industrial use (International Energy Agency, 2023 ; U.S. Energy Information Administration, 2022). Geothermal power is considered a renewable and low-carbon energy source because the heat is continuously replenished naturally. It also offers a stable and reliable supply compared to intermittent renewable sources like solar or wind, making it a key component of sustainable energy strategies (World Energy Council, 2021).

3. Tidal energy

Tidal energy results from the rotation of the Earth in relation to the Earth–Moon system.

Wood, solar energy, hydroelectricity, and wind energy are all derived from solar energy. Only geothermal and tidal energy sources are exceptions to this rule.

Disadvantages of energies

The use of energy involves numerous risks (Kirk R. et al., 2013). Electricity, for instance, can cause serious hazards such as electrocution, burns, blindness from electric arcs, falls resulting from electric shocks, and even fires (Marie Teranne, 2025). The exploitation of hydrocarbons is not without consequences either. Oil spills in the oceans cause severe environmental disasters, such as oil slicks. Gases emitted by vehicles contribute to the destruction of the ozone layer and to global warming. Polycyclic aromatic hydrocarbons (PAHs) are dangerous pollutants found in the air, water, soil, and sediments, particularly in urban and industrial areas. They originate mainly from human activities related to fossil fuel use. These substances accumulate in the environment and pose serious threats to human health. Despite ongoing efforts, their presence continues to increase, notably due to forest fires associated with climate change (Teixeira, J. et al., 2024). Nuclear energy also presents significant dangers. Nuclear power plants release radioactive substances, sometimes in considerable amounts. This radioactivity is extremely harmful to human health, as it can cause cancers and genetic malformations. The Chernobyl nuclear disaster, which occurred on April 26, 1986 (Laurence C.C., 2006), remains the most

catastrophic to date. A steam explosion triggered a fire that released radioactive materials into the atmosphere for ten days, causing severe radiation exposure to a large number of people.

Discussion

Since ancient times, humans have used petroleum, as confirmed by archaeological discoveries. In the Middle East, the Sumerians employed bitumen to coat their statues, waterproof baskets, and seal bricks. Ship caulking was also performed using pitch a petroleum-based substance similar to tar. These materials were collected from natural oil seeps found in certain regions (Alain-Yves Huc, 2025). For decades, petroleum has been at the heart of nearly all human activities. Almost nothing can be accomplished without petroleum involvement. It is present in every industrial sector (Geyer R., J.R. et al., 2014 ; IFA, 2018 ; Levi P.G. et al., 2018). Petroleum serves both as an energy source and as a raw material for the chemical industry, making it simultaneously the main feedstock of the chemical sector and the dominant source of energy worldwide. Fossil fuels (petroleum, natural gas, and coal) account for more than 80 % of global energy consumption far exceeding nuclear power and renewable sources such as hydroelectric, wind, and solar energy (Hagop Demirdjian, 2005). Petroleum is the principal raw material for material transformation industries, unmatched in terms of quantity by any other resource. In Algeria, the petroleum products sector is among the pillars of the national economy. It contributes significantly to the country's wealth creation and serves as a key driver of economic development. Moreover, it plays a central role in the daily lives of the population (Allioui Kawther & Ftissi Imene, 2023). The estimation of global petroleum and natural gas reserves remains a matter of debate. Four main categories of reserves are generally distinguished : proven (confirmed and recoverable), probable (potentially recoverable), possible (yet undiscovered), and non-conventional (such as oil sands and extra-heavy oils). In 1995, proven reserves were estimated at 137.4 billion tonnes, mostly located in the Middle East. Ultimate reserves, including all categories, were estimated at around 215 billion tonnes. Non-conventional reserves represent an equivalent potential, particularly in Canada, the Commonwealth of Independent States (CIS), and Venezuela (France Jeune, 2025). Although the short-term risk of physical oil shortage is considered low, it remains essential to closely monitor the renewal of reserves and their geographic distribution.

Recent conflicts, such as the Gulf War and the Iraq War, have highlighted the strategic importance of petroleum for global economic stability. Within this context, the European Union has made significant progress in developing renewable energy, reaching a 16 % share of final energy consumption in 2014 exceeding the established targets. This transition reduces dependence on fossil fuels and opens new economic opportunities. However, despite these advances, the energy transition still requires substantial effort, particularly among certain member states (Mihai Tomescu, 2021).

Conclusion

Since the oil shocks of the 1970s, petroleum has become a powerful strategic instrument. It has given rise to numerous debates concerning supply, pricing, and the search for viable alternatives. Moreover, petroleum represents a major source of fiscal revenue for many states, placing it at the core of the global economy. It is also worth noting that petroleum played a central role in the Industrial Revolution. It remains the only raw material capable of producing basic substances in sufficient quantity and quality. Petroleum uniquely provides large quantities of synthetic intermediates essential for transformation industries such as pharmaceuticals, food processing, cosmetics, and chemicals. In short, petroleum is present in nearly every industrial sector, making it an essential and indispensable element of human life. Life on Earth, in many ways, depends on the continuous availability of petroleum. Just as the heart needs blood to function, humanity depends on petroleum for its survival. In comparison with so-called renewable energies, petroleum continues to demonstrate its dominance, as renewables have already shown their limitations. In the strict sense, all forms of energy are renewable, since petroleum itself is formed through the decomposition of organic matter originating from the Earth's surface. Therefore, the notion of petroleum depletion may be considered questionable: as long as life exists on Earth, organic matter will continue to accumulate underground, allowing for the possible formation of new petroleum. Humanity itself is composed of organic matter it can thus be said that petroleum flows metaphorically through our veins, making it impossible to separate humankind from petroleum.

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