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The Global Significance of Renewable Energy: Contributions to Economic Growth and Environmental Sustainability

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Abstract: Renewable energy has moved from the margins of the global energy system to its leading edge, reshaping how electricity is generated, traded, and valued. This review synthesises recent evidence on the economic and environmental significance of renewable energy at a global scale. On the economic side, it examines investment trends, employment generation, the levelised cost of electricity (LCOE), energy security, and energy access, drawing on the latest data published by the International Renewable Energy Agency (IRENA), the International Energy Agency (IEA), and the International Labour Organization (ILO). On the environmental side, it reviews the contribution of renewables to greenhouse gas (GHG) mitigation, air quality, and the associated trade-offs in land, water, and material use. The review further discusses the policy architecture supporting the global energy transition, including the Paris Agreement and the COP28 tripling pledge, and identifies the principal barriers that continue to constrain deployment: grid integration and intermittency, storage costs, financing gaps in developing economies, and critical-mineral supply chains. The evidence indicates that renewable energy is no longer solely a climate mitigation tool but has become a central pillar of economic competitiveness, energy security, and industrial policy, while significant regional disparities in investment and employment remain a persistent challenge to an equitable global transition.

Index Terms: Renewable energy, energy economics, greenhouse gas mitigation, energy transition, levelised cost of electricity, energy policy, sustainable development.

I. INTRODUCTION

Energy underpins nearly every dimension of modern economic activity, from industrial production and transport to digital infrastructure and household welfare. For over a century, this activity has been powered overwhelmingly by fossil fuels, whose combustion has driven unprecedented economic growth while simultaneously altering the composition of the atmosphere and degrading air, water, and land systems [1]. The resulting tension between energy-driven prosperity and environmental sustainability has made the transition to renewable energy sources – solar, wind, hydropower, bioenergy, geothermal, and marine energy – one of the defining technological and policy challenges of the twenty-first century.

Over the past decade, this transition has accelerated far faster than most forecasters anticipated. Renewables are no longer a marginal or subsidised technology class; in most parts of the world they are the cheapest available source of new electricity generation [2]. Global renewable electricity capacity additions reached a record high in 2024, and clean energy technologies now attract roughly twice as much global investment as fossil fuels combined [3]. At the same time, the sector directly employs more than sixteen million people worldwide [4], and its expansion has begun to measurably slow – though not yet reverse – the growth of global greenhouse gas emissions [1].

This review article synthesises current evidence on two intertwined dimensions of this transition: its economic contribution and its environmental contribution. Rather than focusing on a single renewable technology or a single country, the review takes a global, cross-sectoral perspective, drawing on the most recent statistical releases from IRENA, the IEA, and the ILO, together with peer-reviewed and policy literature. Section II summarises the current global renewable energy landscape. Section III examines the economic contributions of renewables – investment, employment, cost competitiveness, energy security, and energy access. Section IV reviews environmental contributions, including GHG mitigation, air quality, and resource trade-offs. Section V outlines the policy frameworks that have enabled this growth, Section VI discusses the barriers that remain, and Section VII offers a forward-looking discussion before the review concludes in Section VIII.

II. GLOBAL RENEWABLE ENERGY LANDSCAPE

By the end of 2024, global installed renewable power generation capacity had reached approximately 4,443 GW, following net additions of around 582 GW during the year – the largest annual increase on record [2]. Independent tracking by the IEA places gross global renewable capacity additions even higher, at close to 685 GW in 2024, a 22% increase over 2023, with solar photovoltaics (PV) alone accounting for roughly 80% of the increase [5]. Analysis by the energy think-tank Ember corroborates this trajectory, forecasting a further rise to around 793 GW of additions in 2025 [7]. The discrepancy between IRENA’s and the IEA’s headline figures largely reflects differences in scope and timing of data collection, but both sources agree on the same underlying trend: solar PV and wind now account for the overwhelming majority of new generating capacity added worldwide, a share the IEA expects to remain near 95–96% through 2030 [5, 6].

Geographically, this growth remains heavily concentrated. China alone is expected to install more new renewable capacity between 2024 and 2030 than the rest of the world combined during 2017–2023, and its share of global annual capacity additions is projected to approach 60% by 2030 [6]. The European Union remains the second-largest growth market, while emerging economies in Africa, Southeast Asia, and Latin America continue to lag behind their resource potential, a disparity discussed further in Section VI.

Fig. 1 summarises this trajectory. Global installed renewable capacity rose from 2,799 GW in 2020 to 4,443 GW in 2024 and 5,149 GW in 2025, and is projected to reach approximately 9,530 GW by 2030 under the IEA’s main-case scenario – still short of the COP28 pledge to triple 2022 capacity to at least 11.5 TW [7].

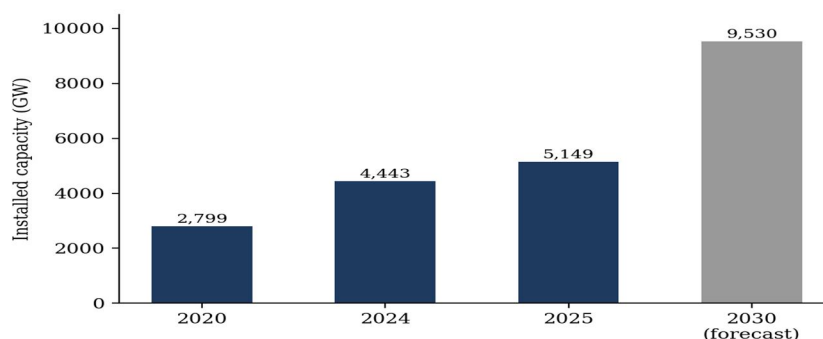


Figure 1: Global installed renewable power generation capacity, 2020–2025, with the IEA main-case forecast for 2030 [1, 5, 9].

In terms of generation, renewables together with nuclear power supplied roughly 80% of the increase in global electricity demand in 2024 [8]. In the European Union, wind and solar reached a record combined share of 28% of electricity generation, surpassing the combined share of coal and gas for the first time, while renewables overall accounted for almost 50% of the bloc’s electricity [8]. The IEA projects that renewables will overtake coal as the single largest source of global electricity generation by the end of 2026 at the latest, supplying almost 45% of world electricity by 2030 [9].

Table 1 collects the headline indicators discussed throughout this review, drawn from the most recent IRENA, IEA, and ILO releases, and provides a single reference point for the economic and environmental figures examined in the sections that follow.

Table 1: Selected Global Renewable Energy Indicators, 2024–2025

Indicator	Value
Total installed capacity (end-2024)	4,443 GW
Net capacity additions (2024)	582 GW
Global renewable employment (2024)	16.6 million
Clean energy investment (2025 est.)	USD 2.2 trillion
Fossil fuel investment (2025 est.)	USD 1.1 trillion
Avoided fossil fuel costs (2024)	USD 467 billion
CO ₂ avoided by 5 key clean technologies (annual, since 2019)	2.6 Gt
Solar PV utility-scale LCOE (2024)	USD 0.043/kWh
Onshore wind LCOE (2024)	USD 0.034/kWh

Sources: IRENA [2]; IEA [1, 3]; IRENA–ILO [4].

III. ECONOMIC CONTRIBUTIONS

A. Investment and Market Growth

Global capital flows to the energy sector are estimated to reach USD 3.3 trillion in 2025, a 2% real-terms increase over 2024 [3]. Of this, approximately USD 2.2 trillion is directed collectively toward renewables, nuclear power, grids, storage, low-emission fuels, efficiency, and electrification – roughly twice the USD 1.1 trillion invested in oil, natural gas, and coal combined [3]. Solar PV alone is expected to attract around USD 450 billion of investment in 2025, making it the single largest destination for energy capital worldwide [10]. This 2:1 ratio in favour of clean energy technologies marks a structural shift from a decade earlier, when investment in clean and fossil energy was roughly balanced [11].

Fig. 2 illustrates this shift: clean energy technologies are estimated to attract roughly twice the capital directed to oil, gas, and coal combined in 2025.

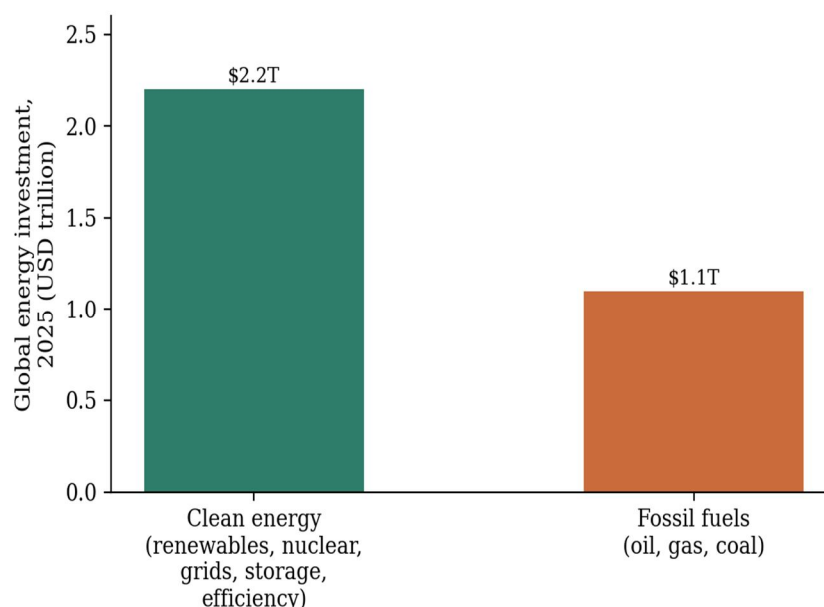


Figure 2: Global energy investment by category, 2025 (estimated) [3].

This investment is not evenly distributed. Africa, home to approximately 20% of the global population, received only around 2% of global clean energy investment in 2025, despite possessing some of the world's richest solar and wind resources [10]. Addressing this imbalance is widely regarded as essential both for global climate goals and for the continent's own industrialisation and energy access ambitions.

B. Employment Generation

Renewable energy has become a substantial source of global employment. According to the eleventh edition of the IRENA–ILO Renewable Energy and Jobs review, global renewable energy employment reached 16.6 million jobs in 2024, up from 16.2 million in 2023 and 13.7 million in 2022 [4]. Solar PV remains the largest employer within the sector, followed by liquid biofuels, hydropower, and wind power, which together accounted for the bulk of the workforce [4].

As with investment, employment gains are geographically concentrated. China accounted for an estimated 7.3 million renewable energy jobs in 2024 – 44% of the global total – reflecting its dominant position in both deployment and equipment manufacturing [4]. The European Union recorded 1.8 million jobs, Brazil around 1.4 million, and India and the United States each slightly more than one million [4]. By contrast, the whole of Africa recorded only around 324,000 renewable energy jobs in 2023 despite its considerable resource endowment [12].

Fig. 3 and Table 2 present this distribution. The 2025 review also notes that employment growth (2.3% year-on-year) has begun to lag behind the much faster growth in installed capacity, a divergence attributed to geopolitical tensions, trade frictions, and rising automation in manufacturing [4].

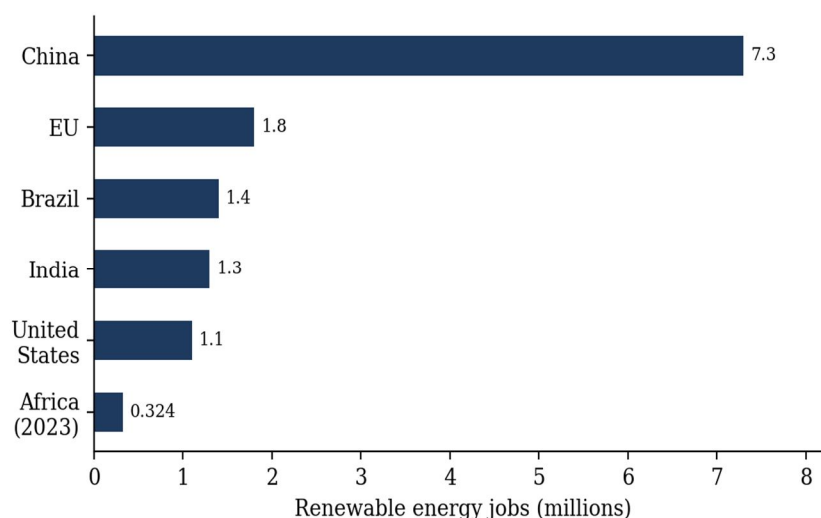


Figure 3: Renewable energy employment by country/region, 2024 (Africa: 2023 figure) [4, 12].

Table 2: Renewable Energy Employment by Country/Region

Country/region	Jobs (million)	Share of global total
China	7.3	44%
European Union	1.8	11%
Brazil	1.4	8%
India	1.3	8%
United States	1.1	7%
Africa (2023)	0.32	2%

Source: IRENA–ILO, Renewable Energy and Jobs, 2024–2025 editions [4, 12].

C. Cost Competitiveness

A central driver of renewable energy's economic significance is the dramatic decline in its cost. According to IRENA's Renewable Power Generation Costs series, the global weighted-average LCOE of utility-scale solar PV fell by roughly 90% between 2010 and 2024, from around USD 0.417/kWh to USD 0.043/kWh [2]. Onshore wind is now the least expensive source of new electricity generation globally at approximately USD 0.034/kWh [13]. Total installed costs have fallen in parallel: by 2024, utility-scale solar PV installed costs had declined by around 87% since 2010, onshore wind by roughly 55%, and battery energy storage systems by approximately 93% [14].

These reductions mean that renewables are frequently the cheapest option for new power generation even without policy support, as summarised in Fig. 4 and Table 3. IRENA reports that 91% of newly commissioned utility-scale renewable capacity in 2024 generated electricity more cheaply than the least-cost new fossil-fuel alternative in the same market, and that this cost advantage allowed renewables to avoid an estimated USD 467 billion in fossil fuel costs globally during the year [2]. Emerging analyses of "firm" renewable power – solar or wind paired with battery storage to provide round-the-clock supply – show costs of USD 54–82/MWh in high-resource regions, already competitive with new coal and gas generation in many markets [15].

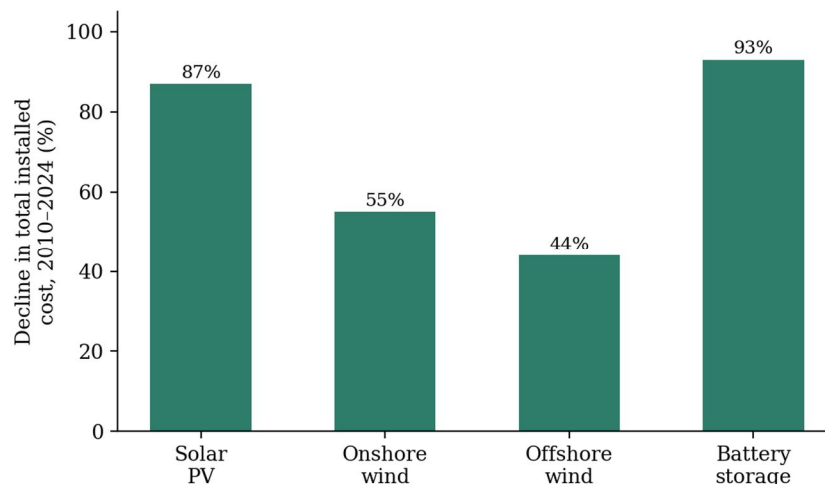


Figure 4: Decline in global weighted-average total installed cost (TIC), 2010–2024, by technology [2, 14].

Table 3: Levelised Cost of Electricity, Selected Technologies, 2024

Technology	LCOE (USD/kWh)	Change since 2010
Utility-scale solar PV	0.043	–90%
Onshore wind	0.034	– (least-cost)
Firm solar + storage*	0.054–0.082	n/a (new metric)

*High-irradiance regions; solar or wind paired with battery storage for round-the-clock supply. Sources: IRENA [2]; pv magazine [13, 15].

D. Energy Security and Import Substitution

Beyond direct cost savings, renewables strengthen energy security by reducing dependence on imported fuels. The IEA estimates that since 2010 the world has added around 2,500 GW of non-hydro renewable capacity, approximately 80% of it in countries that rely on fossil fuel imports [5]. Without these additions, cumulative coal and natural gas imports in those countries would have been around 45% higher in 2023; as it stands, coal imports have been reduced by roughly 700 million tonnes and natural gas imports by about 400 billion cubic metres since 2010, saving an estimated USD 1.3 trillion [5]. In markets exposed to volatile fossil fuel prices, this diversification effect provides a degree of macroeconomic stability that is difficult to achieve through fossil-fuel-based systems alone.

E. Energy Access and Rural Development

In many developing regions, decentralised renewable systems – off-grid solar home systems, mini-grids, and small hydropower – offer a faster and often cheaper route to electrification than extending centralised grids. Because such systems can be deployed with limited transmission infrastructure, they have particular relevance for rural electrification in Sub-Saharan Africa and South Asia, where they also create local entrepreneurship and employment opportunities, particularly where financing and skills barriers for underrepresented groups, including women, are addressed [12].

IV. ENVIRONMENTAL CONTRIBUTIONS

A. Greenhouse Gas Mitigation

The primary environmental rationale for renewable energy deployment is the mitigation of GHG emissions associated with fossil fuel combustion. Global energy-related CO₂ emissions reached a record 37.8 billion tonnes in 2024, but the rate of growth slowed to 0.8%, even as the global economy expanded by more than 3% – a continuation of the decoupling between economic growth and emissions growth observed in advanced economies over the past several years [1].

The IEA attributes a substantial share of this decoupling to the rapid deployment of clean energy technologies: solar PV, wind power, nuclear power, electric vehicles, and heat pumps deployed since 2019 are now estimated to avoid approximately 2.6 billion tonnes of CO₂ emissions annually, equivalent to about 7% of global energy-related emissions [1]. Solar PV alone avoided an estimated 1,658 million tonnes of CO₂ in 2024 through displaced fossil generation – roughly equivalent to the entire power-sector emissions of the United States [16].

Regional data illustrate this effect concretely. In the European Union, energy-related CO₂ emissions fell by 2.2% in 2024, with coal-related emissions down 11%, driven by record wind and solar generation and a partial recovery in hydropower output [8]. In the United States, coal-fired power generation fell to its lowest level in nearly sixty years, with solar and wind surpassing coal in electricity generation for the first time [8].

B. Air Quality and Public Health

Displacing coal- and oil-fired generation with renewables also reduces emissions of particulate matter, sulphur dioxide, and nitrogen oxides, the principal pollutants responsible for outdoor air-quality-related mortality and morbidity. Because these health benefits accrue locally and immediately – unlike the globally diffuse benefits of GHG mitigation – they are often the most persuasive argument for renewable deployment in regions with severe urban air pollution, and are increasingly incorporated into cost-benefit analyses of national energy policy alongside climate considerations.

C. Land, Water, and Material Use

The environmental profile of renewable energy is not without trade-offs. Utility-scale solar and wind installations require significant land area per unit of energy delivered relative to fossil fuel plants, raising land-use planning and biodiversity considerations, particularly for large ground-mounted solar farms and onshore wind corridors that intersect agricultural or ecologically sensitive land. Hydropower, while a mature and dispatchable renewable source, can alter river ecosystems, sediment transport, and downstream water availability. Bioenergy production raises additional land-use and food-security considerations where feedstocks compete with agricultural land.

Renewable technologies also depend on critical minerals – including lithium, cobalt, nickel, copper, and rare-earth elements – for batteries, wind turbine generators, and solar PV components. The extraction and processing of these materials carry their own environmental and social costs, and supply chains remain geographically concentrated, creating a distinct set of sustainability and geopolitical challenges that are discussed further in Section VI. On balance, however, life-cycle assessments in the literature consistently find that the GHG and air-quality benefits of displacing fossil generation substantially outweigh these upstream impacts over the operating lifetime of renewable installations.

V. POLICY FRAMEWORKS AND GLOBAL INITIATIVES

The rapid growth documented above has been enabled by an increasingly coordinated global policy architecture. The 2015 Paris Agreement established the framework of Nationally Determined Contributions (NDCs) through which countries commit to emissions reduction pathways, with renewable energy deployment forming a central pillar of most national strategies. At the 2023 UN Climate Change Conference (COP28), governments agreed for the first time to a collective global goal of tripling installed renewable energy capacity to at least 11.5 TW by 2030 [7].

Progress toward this pledge has been substantial but, on current trajectories, insufficient. The IEA's main-case forecast sees global renewable capacity reaching approximately 9.5 TW by 2030 – a 2.6-fold increase over 2022 levels, but short of the COP28 target [9]. Ember's analysis is more optimistic, noting that annual capacity additions have averaged 29% growth from 2023 to 2025, ahead of the roughly 21% annual growth required to meet the tripling goal, meaning the required pace for 2026–2030 has fallen to a more attainable 12% per year [7]. National policy instruments – feed-in tariffs, competitive auctions, tax credits, and renewable portfolio standards – have each played a role historically, though competitive auctions are rapidly becoming the dominant procurement mechanism worldwide, projected to account for almost 60% of new utility-scale capacity contracted between 2025 and 2030, up from less than 25% in earlier forecasts [5].

Regional approaches continue to diverge. China's Five-Year Plans and its 2060 carbon-neutrality target have anchored the world's largest renewable manufacturing and deployment base. The European Union's climate and energy legislation has driven the continent's transition away from coal. In the United States and China, recent policy and trade uncertainty – including tariffs on renewable equipment and shifting subsidy frameworks – has led forecasters including the IEA to revise 2025–2030 growth projections downward by approximately 5% relative to prior estimates [9], underscoring the sensitivity of the global transition to national policy stability.

VI. CHALLENGES AND BARRIERS

A. Intermittency and Grid Integration

Solar and wind generation are variable by nature, and their growing share of electricity supply increases the technical complexity of maintaining grid stability and reliability. Grid infrastructure investment has not kept pace with the rapid build-out of generation capacity in many markets, creating interconnection queues, curtailment, and reliability concerns that now rank among the principal constraints on further renewable deployment [10].

B. Storage and Firm Capacity

Battery energy storage costs have fallen dramatically, but deploying sufficient storage to provide firm, round-the-clock renewable supply at the scale required for full grid decarbonisation remains costly in many regions, particularly outside high-resource areas where solar-plus-storage is already cost-competitive with fossil generation [15].

C. Financing Gaps in Developing Economies

As noted in Section III, investment and employment gains remain heavily concentrated in a small number of large economies. Weaker policy frameworks, higher perceived investment risk, and limited access to affordable capital continue to constrain renewable deployment in much of Africa, parts of South Asia, and Latin America, despite these regions holding some of the world's best renewable resource potential [2].

D. Critical Mineral Supply Chains

The concentration of critical mineral processing capacity in a small number of countries introduces both economic and geopolitical vulnerabilities into renewable energy and battery storage supply chains, a challenge that parallels, in some respects, the energy security concerns that renewables were intended to alleviate.

E. Social Acceptance and Land Conflicts

Large-scale renewable projects, particularly onshore wind and utility-scale solar, can encounter local opposition related to land use, visual impact, and community benefit-sharing, requiring careful stakeholder engagement and equitable local benefit distribution to sustain public support for continued deployment.

VII. FUTURE OUTLOOK

The trajectory of the evidence reviewed here suggests that renewable energy's economic and environmental significance will continue to grow over the remainder of this decade, even as important uncertainties persist. On current forecasts, renewables are set to become the largest single source of global electricity generation before the end of 2026, with their share of generation rising toward 45% by 2030 [9]. Continued cost declines in solar PV, wind, and battery storage are likely to reinforce this trend, while growing volumes of competitively auctioned capacity should improve price transparency and reduce financing risk.

At the same time, closing the investment and employment gap between leading markets – principally China, the EU, and the United States – and under-invested regions such as Africa will be essential both for global equity and for the achievement of the COP28 tripling goal. Strengthening grid infrastructure and storage deployment alongside generation capacity, diversifying critical mineral supply chains, and maintaining stable, predictable policy environments are likely to be the principal determinants of whether the sector's rapid growth of the past five years can be sustained through 2030 and beyond.

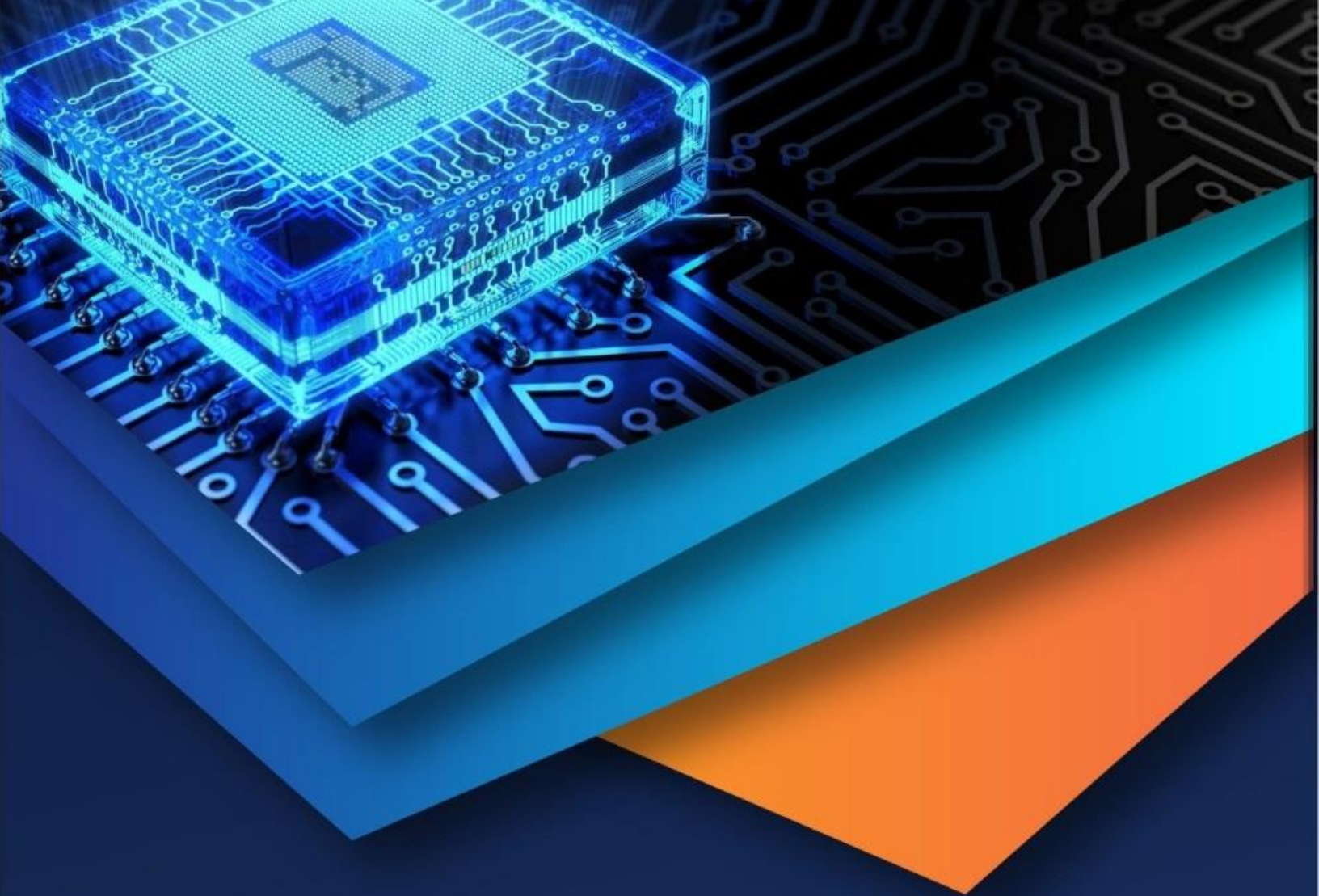
VIII. CONCLUSION

This review has synthesised recent global evidence on the economic and environmental contributions of renewable energy. Economically, renewables have become the least-cost source of new electricity generation in most markets, attract roughly twice the investment directed to fossil fuels, and directly employ more than sixteen million people worldwide, while also strengthening energy security through reduced fossil fuel import dependence. Environmentally, the accelerating deployment of solar, wind, and other renewable technologies is measurably slowing the growth of global greenhouse gas emissions and delivering substantial air-quality co-benefits, even as land-, water-, and mineral-related trade-offs require careful management. The central challenge for the remainder of this decade is not primarily technological but structural: translating the sector's remarkable cost and capacity gains into a more geographically balanced transition, supported by adequate grid and storage infrastructure and by stable policy frameworks, so that the economic and environmental benefits documented in this review can be realised at global scale.



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