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Review Article

A Review: Renewable Energy from an Environmental Perspective

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Abstract: The interrelation between renewable energy (RE) deployment and environmental sustainability is increasingly critical for sustainable development in Iraq, Iran, and Turkey. Iraq possesses abundant solar irradiation and favorable wind corridors, yet renewable energy contributes less than 2% of electricity generation due to policy gaps, financial constraints, and technical limitations. In contrast, Iran and Turkey have implemented structured policies, feed-in tariffs, and private sector engagement, resulting in more significant renewable adoption. Renewable energy offers substantial environmental benefits, including greenhouse gas mitigation, improved air quality, water conservation, and promotion of circular economy practices through biomass and waste-to-energy systems. Effective implementation requires coherent policy frameworks, financial incentives, technical capacity building, and public awareness. Integration of hybrid systems, smart grids, and GIS-based site selection enhances reliability and efficiency, mitigating intermittency challenges. Strategically expanding renewable energy in Iraq can transform the national energy system into a low-carbon, decentralized, and resilient infrastructure. Such a transition supports socio-economic development by creating jobs, improving energy access, and reducing dependence on fossil fuels while contributing to long-term environmental sustainability. Comparative insights from Iran and Turkey provide practical pathways for policy, technology, and institutional development to accelerate Iraq's renewable energy adoption.

Keywords: Renewable Energy, Sustainability, Solar Energy.

1. INTRODUCTION

Energy security and environmental sustainability are increasingly intertwined in global development. Reliance on fossil fuels has led to soaring greenhouse gas emissions, air pollution, and heightened climate fragility. This heavy dependence has resulted in significant carbon dioxide emissions, deteriorating air quality, and depletion of water resources. Furthermore, the impacts of climate change, including rising temperatures and desertification, exacerbate energy security concerns. Globally, countries are turning to renewable energy to reduce greenhouse gas emissions and ensure sustainability. Iraq, with its abundant solar and wind energy resources, has a strategic opportunity to transition to low-carbon, decentralized, and resilient energy systems. The transition to renewable energy aligns with environmental goals, reduces dependence on oil, and delivers socioeconomic benefits by creating jobs and improving access to energy [1, 2]. Integrating renewable energy technologies, such as solar photovoltaic, wind, biomass, and hybrid systems, offers a path toward environmental sustainability and energy security [3, 4]. Iraq faces a dual challenge as one of the world's largest oil producers while simultaneously suffering from chronic electricity shortages, severe environmental pollution, and inefficient energy infrastructure [1, 2].

Electricity generation in Iraq relies primarily on natural gas and oil-fired power plants, which together account for more than 95% of the country's total power production. This dependence has led to chronic greenhouse gas emissions, air pollution, and an unstable power supply [5]. In Iraq, renewable energy contributes less than 2% to the total electricity supply, despite the country's high solar irradiance and extensive wind corridors in the northern and western regions [6, 7]. The disparity between available potential and the current situation points to significant obstacles, including policy gaps, financial constraints, and technological limitations [8]. A regional comparison with neighboring countries, particularly Iran

and Turkey, provides a deeper understanding of the strategic pathways for renewable energy deployment. Iran has gradually implemented policies encouraging renewable energy generation, focusing on small-scale solar, wind, and hydropower projects, achieving modest growth despite geopolitical and economic constraints [9, 10]. Turkey, on the other hand, has successfully expanded its renewable energy portfolio, especially solar and wind power, supported by government incentives and feed-in tariffs, making it a regional leader in renewable energy [11].

2. Renewable Energy

Renewable energy refers to energy derived from naturally replenishing resources, which are practically inexhaustible on a human timescale. These include sunlight, wind, flowing water, geothermal heat, and biomass [12]. Unlike fossil fuels, renewable energy systems have a limited environmental impact during operation and offer a pathway to reducing carbon emissions [1].

In Iraq, the photovoltaic solar energy sector has significant potential, with average solar irradiance of 5.3–6.5 kWh/m²/day in most areas, and approximately 3,000 hours of sunshine annually [13, 14]. Wind energy potential is concentrated in the northern and western governorates, where measured speeds range between 5 and 7 m/s at a height of 50 meters, suitable for large-scale wind turbines [15]. Biomass energy is primarily derived from agricultural waste, animal manure, and municipal solid waste, although its contribution remains limited due to underdeveloped collection and conversion systems [16].

3. Environmental Sustainability:

Environmental sustainability is defined as the responsible use of natural resources to meet current needs without compromising the ability of future generations to meet their own needs [17]. In the energy sector, sustainability includes reducing carbon emissions, minimizing air and water pollution, preserving biodiversity, and ensuring social and economic equity [18]. The United Nations Sustainable Development Goal 7 (SDG7) emphasizes the need to provide affordable, sustainable, reliable, and modern energy for all, reinforcing the importance of deploying renewable energy [19].

The Environmental Benefits of Renewable Energy Include:

1. **Reducing greenhouse gas emissions:** Renewable energy systems produce little to no carbon dioxide emissions, directly contributing to climate change mitigation.
2. **Improving air quality:** Replacing electricity generated from fossil fuels reduces emissions of fine particulate matter (PM), sulfur dioxide (SO_2), and nitrogen oxides (NO_x), which are major contributors to respiratory and cardiovascular diseases.
3. **Water Conservation:** Solar photovoltaic and wind power systems require significantly less water for operation compared to thermal power plants, which consume large quantities for cooling.
4. **Promoting Circular Economy Principles:** The use of biomass technologies and waste-to-energy conversion contributes to enhanced resource efficiency and waste management [20].

4. Integrating Renewable Energy and Sustainability into Policy Frameworks

The theoretical relationship between renewable energy and sustainability rests on three main pillars: environmental protection, economic viability, and social justice. Policy frameworks should include the following:

- **Regulatory Incentives:** Feed-in tariffs, net metering, tax incentives, and renewable energy portfolio standards.
- **Financial Instruments:** Green bonds, subsidies, and concessional loans for renewable energy projects.
- **Technical Capacity Building:** Developing a skilled workforce, research centers, and local manufacturing capabilities [21].

In Iraq, political interventions remain limited, as there is no comprehensive renewable energy law fully implemented at the national level, although pilot programs and international cooperation (e.g., with the International Renewable Energy Agency and the United Nations Development Programme) provide initial frameworks [22]. By comparison, Iran and Turkey have more structured policy environments: Iran uses feed-in tariffs and renewable energy purchase commitments, while in Turkey, renewable energy resource areas (YEKA) and government-backed financing have accelerated adoption [23-25].

Table 1: Comparison of Iraq, Iran, and Turkey with regard to their renewable energy sources

Country	Solar Irradiation (kWh/m²/day)	Wind Speed (m/s)	Current RE Share (%)	Major RE Source	Policy Support
Iraq	5.3–6.5	5–7	<2	Solar, Wind	Pilot programs, IRENA support
Iran	5.0–5.8	6–8	5–7	Solar, Wind, Hydro	Feed-in tariffs, purchase obligations
Turkey	4.5–6.0	6–8	13–15	Solar, Wind, Hydro, Geothermal	YEKA zones, incentives, public-private partnerships

5. CASE STUDIES

Three Case Studies in Iraq, Iran, and Turkey [26]

1. Iraq - Karbala Solar Power Plant (300 MW)
    - Annual energy production: 550 GWh
    - CO2 emissions reduction: Approximately 200,000 tons/year
    - Secondary benefits: Improved energy reliability in Karbala and reduced reliance on fossil fuels.

2. Iran - Manjil and Rudbar Wind Power Plants
    - Installed capacity: 200 MW
    - Environmental outcomes: CO2 emissions reduction of approximately 150,000 tons/year and reductions in local air pollutants

3. Turkey - Soma and Balıkesir Wind Power Plants
    - Combined installed capacity: 1,200 MW
    - Environmental outcomes: Annual CO2 emissions reduction of approximately 1.5 million tons and significant reductions in sulfur dioxide and nitrogen oxide emissions.

These examples demonstrate that deploying renewable energy is not only a technological or economic initiative but also a fundamental strategy for environmental sustainability. By quantifying reductions in emissions, air pollutants, and resource consumption, policymakers can prioritize projects that maximize environmental benefits.

6. CONCLUSION

Iraq, Iran, and Turkey possess significant renewable energy resources. Iraq has high potential in solar and wind power, while Iran has a diversified mix of solar, wind, and small-scale hydropower. Turkey has a well-established portfolio of renewable energy sources. Despite Iraq's abundant resources, renewable energy currently contributes less than 2% of electricity generation due to policy gaps, limited financing, technical challenges, and inadequate grid connectivity. In contrast, Iran and Turkey benefit from well-regulated policies, incentives, and active private sector participation, enabling faster adoption.

The deployment of renewable energy directly supports environmental sustainability by reducing greenhouse gas emissions, improving air quality, conserving water, and promoting circular economy practices. Effective implementation requires regulatory incentives, financing mechanisms, technical capacity building, and community engagement. Hybrid systems, smart grids, and geographic information system (GIS) site selection also enhance reliability and efficiency. The strategic expansion of renewable energy use in Iraq offers numerous socio-economic benefits, including energy security, job creation, and equitable energy distribution, in line with environmental and sustainability goals.

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