Green Energy Transformation: Policy Reversals, Geopolitical Shocks, and the Digital Infrastructure Imperative

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Abstract— **The global energy transition faces a major governance challenge: balancing rapid renewable energy expansion with policy reversals, geopolitical disruptions, and the growing energy demands of Artificial Intelligence (AI) data centers. These pressures risk diverting clean energy gains toward digital infrastructure while leaving energy-insecure nations vulnerable to fossil fuel dependence and unequal digital development. The urgency of this challenge is underscored by record-breaking global temperatures from 2023 to 2025, highlighting the escalating costs of delayed climate action. While previous studies have examined renewable deployment, policy changes, and data center sustainability separately, limited research has explored their combined impacts. This paper addresses that gap by analyzing four interconnected developments: the 2025 global renewable energy surge, which added 793 GW of new capacity; the rollback of U.S. clean-energy policies under the Trump administration; the 2026 Strait of Hormuz closure, which demonstrated that energy security and decarbonization can reinforce one another; and the increasing resource demands of AI-driven data center expansion. Based on these findings, the paper proposes a phased and enforceable policy framework that includes technology efficiency mandates, incentives for strategic data center siting, and automatic safeguards for developing countries. The framework is assessed through comparative case studies from China, India, the Nordic region, Bhutan, and Pakistan. The analysis concludes that energy security and decarbonization are fundamentally aligned objectives. Evidence from the Hormuz crisis showed that renewable-rich economies were more resilient to energy shocks, with Spain experiencing significantly lower electricity price increases than fossil fuel-dependent Singapore. The study also observed substantial gains in clean-energy equities following the crisis, reinforcing the strategic value of accelerating the renewable transition.**

Keywords - Green energy transition; AI infrastructure; Machine learning model sharing.

I. INTRODUCTION

Recent years have underscored the urgency of accelerating the global transition toward low-carbon energy systems. According to the Copernicus Climate Change Service, the years 2023, 2024, and 2025 were among the warmest on record, with global average temperatures exceeding the 1.5°C benchmark established under the Paris Agreement [5]. Climate observations further indicate that the Arctic is warming at a rate approximately three to four times higher than the global average, reflecting a persistent and systemic climate trend rather than a temporary fluctuation [5]. Scientific assessments have demonstrated that a warmer atmosphere retains greater quantities of moisture, increasing both the frequency and intensity of extreme weather events. The Intergovernmental Panel on Climate Change (IPCC) has repeatedly warned that continued warming beyond the 1.5°C threshold may increase the likelihood of irreversible environmental and socio-economic consequences [13].

At the same time, the global energy transition is experiencing both unprecedented progress and significant uncertainty. Rapid deployment of renewable energy technologies has strengthened confidence in the technical feasibility of decarbonization. However, political shifts, geopolitical disruptions, and emerging demands from digital infrastructure are creating new pressures that could reshape the trajectory of the transition. Four interconnected developments are particularly influential.

First, renewable energy deployment reached record levels during 2025, reflecting accelerating investment in solar, wind, and associated clean-energy technologies. Second, changes in United States energy policy introduced uncertainty regarding the long-term stability of climate and clean-energy commitments. Third, geopolitical tensions surrounding the Strait of Hormuz highlighted the continuing vulnerability of global energy markets to supply disruptions and price volatility. Fourth, the rapid expansion of Artificial Intelligence (AI) and large-scale data centers has generated growing concerns regarding electricity consumption, water use, and infrastructure sustainability.

Although these developments are frequently discussed within separate policy and academic domains, their interactions have received comparatively limited attention. Existing studies typically focus on renewable energy expansion, energy security, climate policy, or digital infrastructure as independent subjects. This separation obscures the extent to which these forces collectively influence decarbonization strategies, investment decisions, and long-term energy resilience. The present study addresses this gap by examining these dynamics within a unified analytical framework.

The primary objective of this research is to evaluate how renewable-energy expansion, policy reversals, geopolitical risks, and AI-driven infrastructure growth interact to shape the future of the global energy transition. Building upon comparative evidence from multiple national and regional case studies, the paper develops a policy framework intended to balance climate objectives, energy security, economic competitiveness, and sustainable digital development.

Several limitations should be acknowledged. The analysis is based primarily on publicly available datasets, institutional reports, and secondary literature rather than original field observations. Furthermore, ongoing developments in global energy markets, international politics, and AI technologies may influence future outcomes beyond the scope of the present assessment. While the selected case studies provide valuable insights, they are not intended to represent the full diversity of regional experiences.

The remainder of this paper is organized as follows. Section II examines the four principal dynamics currently shaping the global energy transition, including renewable-energy deployment, policy change, geopolitical risk, and digital infrastructure expansion. Section III evaluates the economic rationale supporting accelerated energy transformation. Section IV presents evidence from circular-economy initiatives and international case studies. Section V proposes a phased policy framework for sustainable digital infrastructure development. Finally, Section VI summarizes the principal findings and outlines policy recommendations for governments, regulators, and industry stakeholders.

II. FOUR DYNAMICS SHAPING THE ENERG TRANSITION

A. *The 2025 Renewable Surge*

The global renewable energy sector is projected to experience an unprecedented expansion in 2025, marking a critical milestone in the global transition toward clean energy systems. Approximately 793 GW of new renewable energy capacity is expected to be added worldwide during the year, representing more than 90% of all new power generation capacity. This trend reflects the accelerating dominance of renewable technologies within the global energy mix [7].

Solar energy remains the primary driver of this growth. According to Ember Energy's *Global Electricity Review 2025*, around 380 GW of solar capacity was installed in the first half of 2025 alone, representing a 64% increase compared to the same period in the previous year [7]. This rapid acceleration highlights the increasing global adoption of solar technologies driven by cost reductions and policy support.

The scale and pace of this expansion demonstrate not only strong international commitment to decarbonization but also the structural transformation of global electricity systems. Rather than merely supplementing fossil fuels, renewable energy is increasingly replacing conventional generation sources, signaling a fundamental shift in energy system architecture.

In addition, the International Energy Agency projects that between 2025 and 2030, approximately 4,600 GW of additional renewable capacity will be deployed globally [11]. This projection builds on current momentum and underscores the long-term trajectory toward renewable dominance in global electricity generation.

Table 1 summarizes key indicators of global renewable capacity for 2024 and 2025, illustrating the scale of this transition and its implications for future energy system development.

TABLE I. GLOBAL RENEWABLE CAPACITY: KEY METRICS (2024–2025)

Metric			
	2024 (Actual)	***2025 (Projected)***	***Source***
Global New Renewable Capacity Added	585 GW	793 GW	(House of Commons Library 2026) [10]
Share of All New Power Generation	92.5%	>90%	(House of Commons Library 2026) [10]
China Solar Installed Base	~750 GW	>1,000 GW	(House of Commons Library 2026) [10]
India Annual Wind+Solar Build	~25 GW	40–45 GW	(House of Commons Library 2026) [10]

China surpassed 1,000 GW of installed solar capacity in 2025, following an additional 210 GW added within six months, exceeding the total installed capacity of the United States as of the end of 2024 [7]. India also recorded strong growth, installing 31.25 GW of solar and wind capacity between April and November 2025, with projections indicating a total annual addition of 40–45 GW, supported by competitive auctions and declining technology costs [7]. Despite this rapid expansion, a key concern remains whether renewable energy systems can consistently deliver investment returns that are competitive with fossil fuel-based generation in the long term.

B. *U.S. Policy Reversal and the Geothermal Exception*

The 2025, United States energy policy overall significantly altered the trajectory of the clean energy transition by rolling back several Inflation Reduction Act (IRA) provisions. Key measures included the removal of wind and solar tax incentives, suspension of federal renewable leasing programs, and the revocation of Electric Vehicle (EV) mandates. Collectively, these actions reduced projected clean energy growth by approximately half by 2035 [9]. In addition, the repeal of the Environmental Protection Agency's greenhouse gas finding created regulatory uncertainty, contributing to the delay or cancellation of over $14 billion in clean energy investments. Despite this policy contraction, Enhanced Geothermal Systems (EGS) emerged as a notable exception. EGS utilizes established oil and gas drilling technologies, including hydraulic fracturing and horizontal drilling, to create engineered geothermal reservoirs in diverse geographic settings. The U.S. Department of Energy estimates that geothermal energy could eventually generate up to three times the output of the current U.S. nuclear fleet by 2050 [26]. Major technology firms, including Google and Meta, have increasingly invested in geothermal ventures to secure stable, 24/7 carbon-free electricity for Artificial Intelligence (AI) data centers, which require continuous and reliable power supply that intermittent renewables alone cannot consistently guarantee [29]. This emerging "triple advantage"—clean generation, baseload reliability, and subsurface energy storage—positions geothermal energy as a complementary pillar within future low-carbon energy systems.

C. *The Hormuz Geopolitical Scenario*

The Strait of Hormuz facilitates the transit of approximately 20–21 million barrels of oil per day, representing nearly one-fifth of global oil consumption and serving as a critical supply route for Asian economies. In 2026, escalating geopolitical tensions culminated in a major disruption of this corridor, significantly reducing global energy flows [10]. As a result, oil supply through the strait declined sharply from over 20 million barrels per day in February to approximately 3.8 million barrels per day by early April, marking one of the most severe disruptions in modern energy markets.

The economic consequences were immediate and substantial. Global crude oil prices surged toward $150 per barrel, while refined fuel prices in key trading hubs such as Singapore exceeded $290 per barrel. According to the International Energy Agency, the crisis could increase global fuel expenditures by $1–2 trillion in 2026, reflecting higher costs rather than increased consumption [12]. In addition, disruptions extended to Liquefied Natural Gas (LNG) and fertilizer markets, affecting approximately 20% of LNG trade and one-third of global fertilizer flows, with disproportionate impacts on import-dependent Asian economies [12].

However, the crisis also highlighted structural differences in energy system resilience. Countries with higher renewable penetration demonstrated greater price stability. For example, Spain, with approximately 57% renewable electricity generation, experienced significantly lower post-disruption electricity price increases compared to fossil fuel-dependent systems such as Singapore. Financial markets also responded to these structural signals, with clean energy Exchange-Traded Funds (ETFs) recording gains between 54% and 118% following the disruption [33]. These outcomes underscore a key systemic insight: renewable-based systems reduce exposure to fossil fuel volatility and improve macroeconomic resilience during supply shocks.

Higher fossil fuel prices may also accelerate electrification trends, including electric vehicle adoption and grid storage expansion. Historically, major energy shocks, such as the 1970s oil crisis and the 2021 Texas grid failure, have reinforced structural shifts toward diversified and electrified energy systems.

D. *The Digital Infrastructure Paradox*

The rapid expansion of Artificial Intelligence (AI) infrastructure presents a growing tension between digital growth and sustainability objectives. The United States alone hosts more than 5,400 data centers, accounting for nearly half of global capacity [23]. Goldman Sachs projects that AI-driven workloads will increase data center electricity demand by approximately 165% by 2030 (Goldman Sachs 2025), while McKinsey estimates sustained annual capacity growth of approximately 33% through the same period [18]. Data center energy demand is expected to double between 2024 and 2026. Northern Virginia, the world's largest data center hub, has already reached vacancy rates below 1%, reflecting extreme infrastructure concentration [3]. A multi-state analysis indicates that data center operations imposed approximately $4.3 billion in system-wide electricity costs in 2024, much of which is redistributed to non-digital consumers through rate structures [6].

Water consumption presents an additional constraint. Large-scale facilities can consume up to 5 million gallons of water per day, comparable to the needs of medium-sized urban populations [28]. In Texas, projected water demand from data centers may reach 399 billion gallons annually by 2030, equivalent to approximately 6.6% of statewide supply [25]. In Loudoun County, Virginia, freshwater consumption has increased by 250% since 2019 due to rapid data center expansion [17].

These trends highlight a structural paradox: while AI systems drive productivity gains, their physical infrastructure imposes increasing pressure on electricity, water, and land systems. Table 2 summarizes these risks and corresponding policy responses discussed in Section VI.

TABLE II. AI DATA CENTER SUSTAINABILITY RISKS AND POLICY RESPONSES

Risk Category	***Current Impact***	***Projected (2030)***	***Policy Response***
Electricity Demand	Data center power to double by 2026 [5]	+165% vs 2024	Dedicated generation

		baseline [13]	>50 MW (Sec. VI-B)
Water Consumption	Up to 5M gal/day per large facility [28]	Texas alone: 399B gal/yr [25]	Zero-water cooling mandate (Sec. VI-A)
Grid Cost Burden	$4.3B in 7-state ratepayer costs (2024) [11]	Accelerating without reform	Citizens-first power allocation
Developing Nation Exposure	No binding safeguards exist	Digital colonialism risk	Automatic protections (Sec. VI-D)
Carbon Footprint	Grid-tied growth in fossil-fuel regions	Structural lock-in risk	PUE ≤1.2; co-located renewables

III. ECONOMIC CASE FOR THE ENERGY TRANSITION

The economic rationale for the energy transition is supported by converging arguments related to cost reduction, risk mitigation, and long-term competitiveness. These drivers have strengthened significantly since 2020, with the primary barrier being institutional inertia rather than economic feasibility.

Renewable and nuclear energy sources are increasingly cost-competitive with new fossil fuel generation. Since 2010, the Levelized Cost Of Electricity (LCOE) for utility-scale solar photovoltaic and onshore wind has declined by more than 85% and 70% respectively, making them among the lowest-cost options for new electricity generation in many markets [15]. However, these comparisons refer strictly to generation costs and should not be confused with retail electricity prices, which also include transmission, distribution, and policy-related costs.

Operational efficiency improvements further strengthen the economic case. Zero-water cooling technologies significantly reduce long-term operational expenditures, while deployment in cold-climate regions can reduce cooling energy demand by 30–40% [11]. In addition, waste heat recovery from data centers can generate supplementary revenue streams, as demonstrated by Eco Datacenter in Sweden [11]. Energy independence also improves price stability by reducing exposure to fossil fuel volatility. Furthermore, green compute infrastructure increasingly benefits from Environmental, Social, and Governance (ESG) investment premiums, attracting institutional capital inflows. A critical but underexplored dimension of efficiency lies in machine learning model sharing. Requiring accessibility of large AI models across organizations—similar to open-source software frameworks—could reduce redundant training processes, lower cumulative energy consumption, and accelerate technology diffusion in developing economies. In parallel, introducing mandatory AI model efficiency standards, analogous to vehicle fuel economy regulations, would create structured incentives for computational efficiency and energy-aware AI development.

IV. CIRCULAR ECONOMY EVIDENCE

Empirical evidence from multiple countries demonstrates that sustainable energy transitions are both economically viable and operationally scalable. Table III presents selected case studies illustrating circular economy applications in energy systems.

TABLE III. CIRCULAR ECONOMY CASE STUDIES IN SUSTAINABLE ENERGY TRANSITION

Location	***Model***	***Key Innovation***	***Outcome***
Falun, Sweden (Eco Datacenter)	Climate-positive data center	Server waste heat (30–32°C) piped to district heating & absorption chillers	Net carbon-negative operation; waste heat monetized as revenue
Bhutan	Sovereign renewable model	100% hydropower; state-owned Bitcoin mining (>$780M revenue)	~33% of GDP; public salaries funded; full domestic value capture
Lancaster, California	Streamlined solar permitting	Permitting time reduced from 6 months to 45 minutes	Unemployment: 17% (2009) to 6% (2023)
Wunsiedel, Germany	Rural sector coupling	Surplus wind/solar integrated with forestry waste processing	Functioning circular rural economy
Norway (Oslo/Trondheim)	Zero-emission urban infrastructure	Zero-emission construction sites; Powerhouse building generates 2× its consumed energy	Net energy surplus supplied to local microgrid

Denmark's North Sea energy island project further illustrates large-scale renewable integration. Upon completion, it is expected to supply electricity to approximately 10 million households, representing a major advancement in offshore energy infrastructure [8].

Collectively, these examples demonstrate that the transition to sustainable energy systems does not necessarily increase costs. Instead, it restructures energy production economics by improving efficiency, enabling revenue diversification, and strengthening system resilience.

V. POLICY FRAMEWORK FOR SUSTAINABLE DIGITAL INFRASTRUCTURE

The economic and operational dynamics outlined above highlight the need for a phased regulatory framework for sustainable digital infrastructure. This framework integrates empirical insights from China, India, the Nordic region, Bhutan, and Pakistan, as discussed in earlier sections. The proposed framework is summarized in Table IV.

TABLE IV. PHASED POLICY FRAMEWORK FOR SUSTAINABLE DATA CENTER INFRASTRUCTURE

PHASE	*Time frame*	*Mandate*	*Expected Outcome*
A- Technology	2025–2027	Zero-water cooling, PUE ≤1.2, heat recovery	15% GHG/energy reduction; eliminate water stress
B – Energy Independence	2025–2030	Dedicated generation for facilities >50 MW	Eliminate grid competition with residents
C– Geographic Rationalization	2027–2035	Tax credits for T<10°C regions; carbon/water pricing	30–40% cooling energy reduction
D– Developing Nation Protections	Immediate	Auto-safeguards: zero-water, on-site gen >20 MW, revenue sharing	Prevent digital colonialism; ensure local benefit
E – Model Efficiency Standards	2026 onward	AI model efficiency analogous to vehicle fuel economy	Reduce computation demand growth; lower energy baseline

A. Technology Mandates (2025–2027)

Zero-water cooling should be mandatory for data centers operating in water-stressed regions (below 1,700 m³ per capita annually). Microsoft's chip-level cooling systems demonstrate up to 15% reductions in energy and emissions while eliminating water consumption [19].

Power Usage Effectiveness (PUE) standards should be capped at 1.2 for new facilities, with legacy systems required to reach 1.3 by 2030. Leading hyperscale facilities operated by Google and Microsoft already achieve PUE values near 1.1 [19].

Heat recovery systems must be integrated into all new facilities, enabling reuse in district heating, agriculture, or industrial processes, as demonstrated in Nordic deployments [11].

B. Energy Independence Framework (2025–2030)

Facilities exceeding 50 MW should be required to secure dedicated generation capacity rather than relying on residential grids. Options include Small Modular Reactors (SMRs), co-located renewable systems, or hybrid renewable-storage configurations [11]. This approach reduces social conflict and prevents competition between industrial and residential electricity demand.

C. Geographic Optimization (2027–2035)

Incentives should prioritize deployment in regions with average annual temperatures below 10°C. Cold-climate siting reduces cooling demand by 30–40% while improving system efficiency [11]. Priority regions include Iceland, Norway, Finland, Canada, and northern Europe.

D. Developing Country Protections

Countries with limited water availability or energy deficits should be subject to automatic safeguards, including mandatory zero-water cooling, on-site energy generation requirements, public water-use monitoring, and revenue-sharing mechanisms. Development financing institutions should enforce compliance to prevent asymmetric resource extraction and ensure equitable development outcomes [21].

E. AI Model Efficiency and Sharing

Mandatory efficiency standards for AI systems should be introduced, similar to Corporate Average Fuel Economy (CAFE) standards in transportation. In addition, large-scale AI models should be subject to structured sharing frameworks to reduce redundant training, lower aggregate energy consumption, and improve access for developing economies [18].

V. CONCLUSION

In 2025, global renewable capacity additions reached approximately 793 GW, representing over 90% of all new electricity generation [7]. While this marks significant progress compared to 2024 levels, current deployment remains insufficient to meet long-term climate stabilization pathways.

Policy uncertainty in major economies continues to constrain investment, while AI-driven infrastructure expansion introduces new structural demand pressures [9]. However, evidence from recent geopolitical disruptions indicates that renewable-intensive systems exhibit greater resilience to energy price shocks and supply chain instability [10].

The central finding of this study is that energy security and decarbonization are not competing objectives but structurally aligned systems outcomes. The limiting factor is not technological capability but governance design and policy coordination.

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