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Comparative Analysis Of Challenges In Electric Power Transition Under The Global Low-Carbon Economy Initiative

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KEYWORDS

Power System Transition;

Energy Trilemma, Comparative Analysis;

Multinational Collaboration

ABSTRACT

In the global transition to a low-carbon economy, structural contradictions within electric power systems have become a core obstacle to achieving climate goals. Using Russia, Germany, and China as case studies, this article employs a comparative case study approach to analyze the inherent conflicts in resource-dependent, policy-driven, and scale-economic transformation models. Moving beyond descriptive analysis, the study identifies a central trilemma of "security, equity, and sustainability" that underpins these challenges. It proposes two pathways — "dynamic adaptive policy design" and "a new international cooperation framework"—to address the central question:"How to construct a multinational collaborative path for power system transformation under the global low-carbon economy initiative."

INTRODUCTION

Global climate governance faces unprecedented urgency. According to the IPCC Sixth Assessment Report, global CO_2 emissions must be reduced by 43% by 2030 to limit temperature rise to 1.5°C [1]. However, the low-carbon transition of energy and power systems shows significant divergence: developed countries face technical and economic challenges in "replacing existing capacities," while developing nations struggle with the conflict between "growing demand" and "emission reduction responsibilities" [2]. While extant literature extensively documents the technological and economic hurdles in individual national contexts, a critical gap remains in comparative analyses that dissect the underlying political economy and structural contradictions across divergent transition models. Russia, Germany, and China exemplify resource-dependent, policy-driven, and scale-economic transformation models, respectively. Their divergent paths reflect deep-seated contradictions in the global transition. This article aims to fill this gap by conducting a comparative analysis of these three paradigmatic cases, with the ultimate goal of exploring feasible multinational collaborative pathways. The central research question is: "How can multinational collaboration overcome the divergent challenges in power system transformation under the global low-carbon economy initiative?"

2.Energy Development Challenges in the Low-Carbon Economy

2.1.Russia: Lock-in Effects of Fossil Fuel Dependencyand Geopolitical Isolation

As the world's third-largest natural gas producer, Russia is trapped in a "self-reinforcing cycle" driven by a political economy centered on hydrocarbon revenues and the power of entrenched energy oligarchs. in 2023, gas export revenues reached $340 billion (45% of the national budget), yet only 3% was invested in renewables [5]. Siberia's "blue hydrogen project," based on methane reforming with CCUS, revealed that producing 1 ton of hydrogen consumes 9 tons of freshwater and emits 8.5 tons of CO_2 (60% captured) [5]. Additionally, every 10,000-ton production capacity reduces local river flow by 3.7%, creating long-term ecological risks. EU carbon tariffs and technological sanctions further restrict Russia's hydrogen export market, exacerbating its technological isolation and limiting

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access to critical clean energy technologies.

2.2.Germany: Industrial Backlash from Aggressive Coal Phase-Out Amidst Domestic Political Pressures

In 2023, Germany' s energy transition costs became evident: industrial electricity prices surged to € 0.42/kWh, prompting BASF to shift € 4 billion in investments to China [6]. This policy-driven transition, largely propelled by the political influence of the Green Party and a strong environmental movement, has created a tangible conflict between environmental goals and industrial competitiveness. To compensate for baseload shortages, lignite usage increased by 13%, raising the power sector' s carbon intensity to 0.48 tons CO_2 /MWh (+5% from 2022) [3]. High renewable penetration (50 GW planned) coupled with low grid flexibility led to 15 TWh of curtailed wind energy (7% of annual output) [3]. These contradictions highlight the tension between ambitious domestic climate policy and the realities of a globalized economy.

2.3.China: Scale Dilemmas in Coal Power Transition <mark>and Subnational Governance Challenges

Despite exceeding 1,000 GW in renewable capacity, coal still accounts for 53% of power generation [7]. The central government's "dual carbon" goals often clash with subnational priorities of economic growth, fiscal stability, and employment. Provinces like Shanxi and Inner Mongolia face "structural unemployment": closing 1 GW of coal capacity displaces 2,000 workers, while renewables absorb only 30% [4]. The Ordos "coal+CCUS" pilot project shows capture costs of $65/ton — triple local carbon prices. Regional disparities are stark: coal contributes 30% of Shanxi' s GDP, while eastern provinces like Zhejiang better integrate renewables, revealing a core challenge of equitable and coordinated transition across a vast and heterogeneous nation.

3.Comparative Analysis of Transition Pathways and Core Contradictions

3.1.Transition Pathway Comparison

Pathway	Case Study	Challenges	Cross-Country Comparison
Renewable Scaling	Germany: North Sea Wind Farms (50 GW)	Land-use conflicts: 178 km²/GW vs. fishing opposition	China: Qinghai solar land costs rose 300% (2018–2023)
Cleaning Conventional Energy	Russia: Siberian Blue Hydrogen	CCUS costs: $65/ton (30% profitability)	China: coal+CCUS raises generation costs by 40%
End-Use Electrification	China: 120M EVs by 2030	Grid peak demand: 8 GW gap requires $20B investment	Germany: heat pumps cost €15,000/household → low adoption

Table.1. Transition Pathway Comparison

3.2.Core Contradictions: The "Security-Equity-Sustainability" Trilemma

The case studies reveal that transition challenges are not merely technical or economic, but manifestations of a deeper "trilemma" between Energy Security, Socioeconomic Equity, and Environmental Sustainability.

Russia's pathway is predominantly constrained by the security imperative of maintaining fossil fuel revenue, which directly conflicts with long-term sustainability and, due to ecological impacts, local equity.

Germany's model prioritizes sustainability through aggressive decarbonization, which has undermined its economic security (industrial competitiveness) and raised equity concerns regarding energy affordability.

China's scale-driven approach is caught between the equity demands of regional development and employment and the sustainability goals of the central government, with energy security currently still reliant on coal.

These contradictions reveal that the transition is not a mere technological substitution but a complex socio-political struggle among vested interests, technical path dependencies, and geopolitical constraints that can be usefully framed through this trilemma lens (Fig. 1).

4.Recommendations for Multinational Collaboration

4.1.Dynamic Adaptive Policy Design

Country	Policy Recommendation	Measures
Germany	Carbon Price-Competitiveness Mechanism	Allocate 30% of carbon tax revenue to subsidize energy-intensive industries
China	Differentiated Coal Phase-Out	Set transition periods (15 years for Shanxi, 7 years for Zhejiang)
Russia	Fossil Revenue Transition Fund	Mandate gas exporters to invest 5% of income in hydrogen R&D

Table.2. Dynamic Adaptive Policy Design

4.2.A New International Cooperation Framework: Potentials and Pitfalls

While politically challenging, innovative cooperation frameworks are essential. The following proposals are presented with an explicit analysis of their feasibility constraints.

Eurasian Green Energy Corridor: Link German wind and Siberian solar via China-Russia HVDC technology. (Feasibility Challenge:) This requires standard harmonization and, most critically, a resolution to current geopolitical sanctions and trust deficits, which presently render this proposal largely aspirational.

Debt-for-Transition Mechanism: Allow developing nations to convert 30% of fossil debt into clean energy investments with IMF guarantees. (Feasibility Challenge:) This depends on the willingness of creditor nations and complex multilateral negotiations, but offers a tangible incentive for Global South participation.Global Green Hydrogen Certification: Track carbon footprints via blockchain and establish mutual recognition standards. (Feasibility Challenge:) This is a more immediately actionable proposal, though it faces hurdles in technical standardization and competing national interests.

Conclusion

The global low-carbon transition faces profound contradictions between unified goals and divergent paths, conceptualized in this study as the "security-equity-sustainability" trilemma. Solutions require balancing:Short-term: Accept "imperfect transitions" (e.g., China’s gradual coal phase-out, Germany’s reserve coal capacity) as necessary compromises within the trilemma.Mid-term: Foster pragmatic collaboration via mechanisms like the potentially more viable "Debt-for-Transition Mechanism," while building trust for larger projects.Long-term: Develop "bridge technologies" like long-duration storage and hydrogen metallurgy to ultimately reconcile the trilemma.The success of the global transition is contingent upon a delicate balance among policy, technology, and, most importantly, a clear-eyed recognition of the competing imperatives that define each nation's journey.

REFERENCES

1. IPCC. (2023). Climate Change 2023: Synthesis Report. Geneva: IPCC Press.
2. IEA. (2023). World Energy Investment 2023. Paris: OECD Publishing.
3. German Federal Ministry for Economic Affairs and Climate Action. (2023). Energy Monitoring Report 2023. Berlin: BMK Press.
4. Zhang, X., Li, Y., & Wang, H. (2023). Reconciling Coal Phase-Out with Employment Transition in China. Nature

Energy, 8(6), 532–541.

5. Russian Ministry of Energy. (2023). National Energy Strategy 2023–2035. Moscow: Energy Press.
6. European Commission. (2023). EU Hydrogen Strategy 2.0. Brussels: EU Publications Office.
7. National Energy Administration of China. (2023). Renewable Energy Development White Paper. Beijing: NEA Press.
8. Gu, Y., Lin, H., & Zhao, W. Li, M..., & Wang, X.(2025). Th e Ethical Balance Reconstruction of Green Finance Empowe red by Computer Technology. International Journal of Accou nting and Economics Studies, 12(6), 580-586.
9. Gu, Y., Pan, D., Yang, N., & Wang, X. (2025). Research on Storage and Transportation Cost Control and Technological Breakthroughs from the Perspective of Global Hydrogen Ene rgy Development. Journal of Sustainable Built Environment, 2(5), 33-38.