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Multi-factor Interactions in Global New Energy Policies: Comparative Practices, Impacts, and Optimization Paths

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Abstract:

Against the backdrop of the global energy transition and worsening environmental issues, new energy has become the key to addressing energy and environmental dilemmas. This article systematically reviews the development paths and policy practices in the new energy sector of representative countries such as Thailand, France, the United States, and Germany, and analyzes policy impacts from three dimensions: public participation, environmental protection, and urban sustainable development. The research finds that each country has formed a differentiated development model based on its resource endowment. Policies have promoted industrial upgrading through legal guarantees and economic incentives, but challenges exist, such as uneven cost sharing, insufficient policy targeting, lack of stability, and poor interest coordination. Data shows that new energy policies have effectively raised public environmental awareness, reduced carbon emissions and pollutant concentrations, optimized urban energy structures, and facilitated economic transformation. Based on this, the article proposes suggestions such as reasonable cost sharing, precise policy optimization, maintaining stability and consistency, strengthening multi-party collaboration, and international cooperation, to provide theoretical and practical references for improving the new energy policy system and promoting global energy transition.

Keywords: New energy policy; Energy transition ;Public participation; Sustainable urban development

1. Introduction

Against the backdrop of rapid technological and industrial development, the extensive use of traditional fossil fuels has led to environmental issues such as air pollution, water damage, and soil degradation. The increase in carbon emissions has posed a severe challenge to sustainable development. Renewable energy sources like solar and wind power, with their

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advantages of being clean, pollution-free, and widely available, have become the key to resolving the energy and environmental dilemmas. Currently, countries around the world have introduced various support policies for new energy, including research and development subsidies and tax incentives. The academic community has also conducted numerous studies in specific policy areas.

However, existing research mostly focuses on single-factor analysis, neglecting the synergistic effects of multiple factors such as public participation, environmental benefits, and urban development. This limits the comprehensive exploration of the complex mechanisms behind policy implementation, a notable gap in existing research[1].

Globally, the newly installed capacity of renewable energy reached approximately 470 million kilowatts in 2023, accounting for 86% of new installed capacity in the power industry, with investment in the global renewable energy sector reaching approximately 638 billion US dollars, a record high[1]. These data highlight the accelerated global transition to renewable energy, yet academic research still lacks in-depth analysis of multi-factor interactions in this process.

This paper, with the theme "Global Practices and Optimization Paths of New Energy Policies under Multi-factor Interactions", aims to explore the differences in new energy development paths adopted by different countries based on their resource endowments and the correlation between these paths and policy designs, analyze the interactive impacts of multi-dimensional factors on policy implementation effects, identifies common issues in current policies regarding cost-sharing, targeting, stability, and interest coordination, and explore the construction of a policy optimization system that balances efficiency and fairness. The research employs literature review and comparative analysis methods, drawing on academic literature and government reports, and selects representative countries such as Thailand, France, the United States, and Germany for multi-dimensional comparative analysis. This study can theoretically fill the research gap in single fields, improve the academic system; and in practice, provide references for policy-making in various countries, predict potential challenges in cost-sharing, technological innovation, and other aspects, and offer theoretical support and practical guidance for global energy transition and the achievement of sustainable development goals.

2. Development in the Field of New Energy and Existing Policies

2.1 The Development of New Energy in Various Countries in Recent Years

Amid the global energy transition, countries have explored differentiated paths in the new energy sector based on their resource endowments and development needs, with technological breakthroughs and scale expansion as core priorities.

As an important fulcrum for the development of new energy in ASEAN, Thailand has rapidly risen by virtue of its abundant solar and biomass energy resources and an open business environment. Since clarifying the direction of renewable energy development in 2015, the proportion of grid-connected installed capacity of biomass and solar power, which it has focused on, has continued to rise. By the first half of 2023, the cumulative installed capacity of photovoltaic power had reached 3.18 gigawatts, and projects such as the Ubon Ratchathani floating photovoltaic power station have achieved an annual reduction of 1.4 million tons of carbon dioxide through energy storage technology. More notably, Thailand has emerged as a force in the electric vehicle sector. In the first half of 2025, the registration of battery electric vehicles (BEVs) increased by 52% year-on-year, with a cumulative total exceeding 203,000 units. Relying on its geographical advantages, it has become a core hub for the new energy vehicle industry in Southeast Asia[2].

France has undergone an energy structure transition from "nuclear power dependence" to "diversified renewables". While nuclear power still accounted for 76.93% of total power generation in 2014, its transformation pace has accelerated significantly since 2015, with continuous growth in wind and photovoltaic installations over the years[3]. In 2023, the newly installed photovoltaic capacity reached 3.14 gigawatts, and the cumulative scale exceeded 17 gigawatts. Moreover, it has set targets of reaching 60 gigawatts by 2030 and 100 gigawatts by 2050. By setting stepwise development goals, it gradually reduces its reliance on nuclear power, and the weight of renewable energy in the power structure is constantly increasing[4].

The development of the United States is characterized by technological breakthroughs driving industrial upgrading. The maturity of shale gas extraction technology has completely transformed its energy landscape. In 2009, its

natural gas production ranked first globally, and in 2014, it achieved energy self-sufficiency and began to export. Meanwhile, the capacity of renewable energy doubled to 55.6 GW from 2008 to 2012, with an additional 18 GW of new installations in 2015[5]. In recent years, solar energy and energy storage have become new growth points. It is expected that the cumulative installed capacity of solar energy will double from 2023 to 2026, and the new installed capacity of battery energy storage may increase by 70% in 2025[1]. The advancement of smart grids and supporting facilities for new energy vehicles further supports the in-depth development of the industry.

As a pioneer in energy transition, Germany has continuously led in the large-scale application and technological innovation of renewable energy. In 2024, the share of renewable energy in power generation reached 59.4%, far exceeding the EU average. Wind energy accounted for 31.5% and photovoltaic energy 13.8%, forming a pattern dominated by wind power with rapid growth in photovoltaic energy[6]. In the field of energy storage, Germany has undergone a transition from household storage to large-scale storage: over the past decade, the cumulative installed capacity of household storage reached 15.8 GWh, but new installations in 2024 decreased by 12% year-on-year. Meanwhile, the large-scale storage market has grown rapidly due to the application of technologies such as AI intelligent dispatching and modular systems, providing crucial support for achieving the goal of an 80% renewable energy share by 2030 [6].

2.2 New Energy Policies of Representative Countries

New energy policies in various countries are all goal-oriented, promoting industrial implementation through legal guarantees, economic incentives and mechanism innovation, and the policy focus is dynamically adjusted according to the development stage.

Thailand has built a policy system centered on long-term planning, featuring "goals - incentives - management". The "New Energy Development Plan 2025-2036" clearly sets the targets of 20% of new energy in power generation and 30% in terminal consumption, and refines the paths through sub-plans such as the Energy Development Plan (PDP2025)[2]. To attract investment, the Board of Investment (BOI) offers 8 years of tax exemption, import duty exemption and feed-in tariff (FiT) subsidies. Multiple departments are involved in management, with a dedicated department responsible for implementation. For the emerging field of electric vehicles, the 2025 policy has been further optimized: extending the registration period of the EV3/EV3.5 plan, encouraging overseas market expansion through "export conversion compensation", and at the same time strengthening supervision to ensure the targeted implementation of subsidies, forming a full-chain policy support[2].

French policies balance the goals of transformation with EU coordination, emphasizing the integration of legal frameworks and market tools. The 2005 Energy Basic Law established the position of nuclear power while reserving space for the development of renewable energy. The 2015 Green Growth Energy Transition Law set mandatory targets: reducing the share of nuclear power to 50% by 2025 and increasing the share of renewable energy to 40%, with emission reduction targets higher than those of the EU[3]. At the implementation level, France guarantees returns through fixed feed-in tariffs, reduces costs by exempting photovoltaic value-added tax, and optimizes resource allocation by establishing wind energy development zones (ZDE). For new energy vehicles, policies focus on infrastructure and consumer guidance: planning to build 400,000 charging stations by 2030, phasing out fuel vehicle sales by 2035, allocating 1.5 billion euros in 2024 to support production and consumption, and dynamically adjusting subsidies - reducing purchase subsidies as costs decline and increasing penalties for high-emission vehicles to maximize policy effectiveness.

U.S. policies are based on legislation, emphasizing financial support and technology orientation, and adjusting priorities according to the stage of the industry. The American Recovery and Reinvestment Act of 2009 allocated 16.8 billion U.S. dollars to support energy efficiency and renewable energy initiatives, and issued clean energy bonds to inject capital into the sector [5]. The Clean Energy Security Act established phased emission reduction targets and introduced a "cap-and-trade" mechanism to drive low-carbon transformation. The Energy Act of 2010 provided detailed support measures such as direct subsidies and tax incentives. In the early stage, policies focused on shale gas development, renewable energy grid connection and smart grid construction, promoting the achievement of non-hydro renewable energy installed capacity targets. However, recent policies have shifted, with some subsidies being cancelled, reflecting the flexibility of its policies in response to changes in domestic energy strategy

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and economic environment.

German policies center on legal revisions as the core tool, while also taking into account technological innovation and transformation efficiency. The Renewable Energy Sources Act has undergone eight revisions, continuously optimizing from electricity price adjustments to grid connection management, ensuring orderly competition in the industry. The National Hydrogen Strategy and its action plan have clearly defined the technological route, consolidating Germany's leading position in global hydrogen technology. To overcome development bottlenecks, Germany has revised laws including the Onshore Wind Energy Act and the Federal Nature Conservation Act to remove policy barriers. For instance, it has simplified the land approval process for photovoltaic and wind power projects and allowed enterprises to self-declare access to land registers, accelerating the implementation of large-scale projects[6]. This series of policies not only anchors long-term goals but also resolves phased issues through dynamic adjustments, forming a resilient transformation support system.

3. The Impact of New Energy Policies in Different Countries

3.1 Public Participation Data (Policy Acceptance, Public Feedback, etc.)

US surveys show most people in most states support the Renewable Portfolio Standard (RPS), with over 60% support in Northeast/wind-rich states and over 75% in Vermont/New York[7]. Highlighting job creation potential increases support by 7%, while emphasizing air quality improvements raises it by 6.7%; conversely, a $2 monthly electricity price increase reduces support by 6%.

French attitudes toward new energy policies have transformed. Before the Fukushima nuclear crisis, over 60% of the public supported nuclear power as a means to ensure energy security. After the crisis, growing concerns about ecological risks reduced support to approximately 50%. Between 2011 and 2015, the "Energy Citizens Initiative" saw an 80% increase in participants. This prompted the government to adjust the energy structure, passing the "Green Growth Energy Transition Law" with 62% support. A 2022 survey revealed 78% backed solar and wind energy, 65% supported reducing nuclear power, and 60% would pay more for clean energy[3].

The EU promotes policy acceptance via public participation. In Germany, community energy projects let residents invest in renewables. In 2022, 40% of wind and PV projects were community - owned, with Bavaria's community PV seeing 53% participation and 85% public acceptance of new energy. This reduces policy implementation resistance and shortens project approval time by 30%. Denmark uses national referendums for energy decisions, growing wind power from 0 to 55% from 1980 - 2020, with public consultations for each plan, shortening wind project construction by 25% compared to the EU average. The Netherlands' "energy cooperative" cover 20% of households, achieving 79% policy satisfaction[8].

3.2 Environmental Protection Data Improvement (Carbon Emissions, Air Quality)

The positive impact of new energy policies on environmental protection is evident in France's experience. As a major nuclear power country, France has significantly reduced emissions by relying on nuclear energy for about 75% of its electricity since the 1970s[8]. According to the International Energy Agency, France's carbon emission intensity per unit of GDP had fallen by over 40% compared to 1990 levels, largely due to its low-carbon power sector. After the Kyoto Protocol took effect in 1997, France further promoted low-carbon transitions in transportation and construction through electric vehicles and green building standards. By 2015, the country's total carbon emissions had decreased by 25% compared to 1990. With the implementation of the "Green Growth Energy Transition Law," France aims to increase renewable energy in power generation to 40% by 2030. The large-scale use of nuclear energy has enabled France to ensure energy security while controlling carbon emissions—its power sector's carbon intensity is only one-fifth of the EU average.

The EU has driven regional emission reductions through a unified policy framework. Under its 2020 Climate and Energy Package, the bloc set a 20% renewable energy target—and ultimately achieved 22%, a 12-percentage-point increase from 2005. During the same period, carbon emissions fell by 24% compared to 1990. Germany's Energy Transition Act accelerated its shift from nuclear to renewables. By 2022, wind and solar accounted for 42% of installed capacity, helping cut emissions by 48% from 1990 levels, making Germany an EU leader in decarbonization. At the regional level, Bavaria significantly improved air quality by promoting distributed solar and biomass heat-

ing. By 2022, the number of days with good air quality in winter had increased by 68 compared to 2010, and acid rain occurrence dropped by 70%, demonstrating clear environmental benefits[6].

3.3 Improving Data for Urban Sustainable Development (Energy Structure, Urban Environment, etc.)

New energy policies have greatly optimized national energy structures and supported sustainable urban development. In France, decades of nuclear power development have raised its energy self-sufficiency rate from 22.7% in 1973 to 59% in 2020, greatly reducing dependence on imported fossil fuels. Clean energy consistently makes up over 90% of its electricity mix, with nuclear power contributing 70%, hydropower 10%, and other renewables 10%, forming a highly stable and reliable energy supply system. The "Green Development Energy Transition Law" has further diversified the energy mix by promoting renewables. By 2022, France's installed capacity of wind and solar power had increased by 80% compared to 2015. Cities like Paris have developed smart grids and expanded EV charging networks. As a result, renewable energy accounted for 28% of the city's electricity consumption in 2022—a 15-percentage-point increase from 2015. Grid stability has also improved, with power outage frequency dropping by 35%.

Germany's energy transition has significantly transformed its urban energy systems. Driven by the Renewable Energy Act and feed-in tariffs, the installed capacity of wind and solar power surged from 6 GW in 2000 to 132 GW in 2022, making up 46% of the country's total power capacity. Cities such as Berlin and Munich have developed smart grids and decentralized energy systems. By 2022, renewables met 35% of Berlin's electricity demand, cutting transmission losses from 8% to 4% since 2010. The energy transition has also spurred economic transformation—the renewable sector employed 300,000 people in 2021, and Berlin saw a 120% increase in green energy firms since 2010. [6] Munich reduced building-related carbon emissions by 42% compared to 2010 through solar energy integration and heat pump promotion—alleviating the urban heat island effect.

In the United States, new energy policies have enhanced energy independence and urban innovation. The shale revolution transformed the U.S. into a net energy exporter, achieving 97% energy self-sufficiency by 2020. EV infrastructure expanded rapidly, with public charging stations growing sixfold since 2015 to 130,000 in 2022. San Francisco reached a 25% new energy vehicle adoption rate, helping cut inner-city NOx levels by 38% from 2015. Austin developed a 100% renewable-powered micro grid, enabling data centers to reach 92% clean energy use and establishing a "zero-carbon data cluster," attracting tech companies and supporting high-value urban growth[9].

4. Potential Issues and Recommendations

4.1 Current Policy Shortcomings

The implementation of renewable energy policies across nations has revealed several systemic challenges that hinder effective energy transition. Cost allocation emerges as a particularly sensitive issue, where even modest electricity price increases significantly erode public support. In the U.S., a mere $2 monthly hike reduces approval for Renewable Portfolio Standards by 6%, with more substantial increases causing greater opposition[7]. This cost sensitivity disproportionately affects lower-income populations, exacerbating social inequalities in the energy transition process. Germany's experience with renewable energy surcharges reflects similar challenges, where rising household energy costs have sparked widespread public protests.

Beyond cost concerns, policy effectiveness varies considerably across different renewable technologies. Current incentive structures often fail to address critical technological bottlenecks, resulting in operational inefficiencies like the 8-12% wind power curtailment rates seen in some regions due to inadequate storage solutions. The solar sector faces unique challenges, including technological homogenization and inadequate support for next-generation innovations. These technological gaps are compounded by policy design flaws, particularly in regional contexts where uniform standards - like the EU's emission targets - create implementation disparities between nations with varying resource endowments and energy infrastructures.

Policy instability presents another significant barrier, as evidenced by frequent reversals in renewable support mechanisms. The U.S. has seen numerous states roll back renewable mandates, with immediate negative impacts on investment flows and project development. Similar inconsistencies in France's nuclear policy have created

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uncertainty that undermines long-term planning and R&D investment. Perhaps the most pressing challenge is structural conflict with incumbent energy systems: powerful fossil fuel interests have successfully blocked numerous clean energy initiatives, while regions dependent on traditional energy industries struggle with economic transition.

4.2 Policy Recommendations

Addressing these challenges requires a comprehensive, multi-faceted policy approach that balances technical, economic and social considerations. A critical first step involves redesigning cost allocation mechanisms to ensure equitable burden sharing. Potential solutions include using carbon pricing revenues to offset consumer costs, implementing progressive pricing structures, and developing targeted support programs for vulnerable populations. The success of initiatives like France's zero-interest eco-loans illustrates how well-designed programs can simultaneously advance energy transition goals while delivering tangible benefits to households.

Technological advancement requires more refined policy instruments that account for the distinct development stages and requirements of different renewable energy technologies. This includes tailored R&D support for emerging technologies, performance-based incentives for mature technologies, and targeted solutions for specific integration challenges like energy storage and grid flexibility. Regional policy frameworks must account for local conditions and capabilities, combining overarching targets with flexible implementation pathways.

Ensuring policy stability is equally critical, which requires institutional mechanisms to maintain commitment across political cycles. This could involve establishing cross-party agreements, creating independent energy transition authorities, and developing transparent policy review processes that allow for adjustments while maintaining long-term direction. The political economy of energy transition also requires careful management, through inclusive stakeholder engagement processes, just transition programs for affected workers and communities, and strategies to align incumbent energy interests with decarbonization objectives.

Finally, international cooperation must be strengthened across multiple dimensions - harmonizing standards and regulations, facilitating technology transfer, and mobilizing financial resources for developing economies. The existing architecture of climate finance and technology partnerships provides a foundation but needs significant scaling-up and operational improvements to meet the challenges of global energy transition. By addressing these various dimensions in a coordinated manner, policymakers can develop more effective, equitable and durable renewable energy frameworks.

5. Conclusion

Renewable energy has become central to global climate action and sustainable development, with diverse national experiences demonstrating both the potential and challenges of current policies. Thailand's solar and EV industry boom, Germany's 59% renewable electricity share, and America's shale gas revolution highlight how successful policies align with local resources and industrial conditions. These approaches have delivered measurable results: 85% public acceptance in the EU, France's a 40% reduction in carbon intensity, and German cities sourcing 46% of power from renewables.

Yet significant challenges remain. Cost disparities undermine social equity, as seen when U.S. low-income households showed 18% lower policy support due to electricity price hikes, while Germany's renewable surcharges sparked protests. Policy gaps also persist, with 12% wind curtailment in some areas revealing inadequate storage solutions, and inconsistent regulations causing investment drops like America's 40% decline in wind funding after policy changes.

Moving forward, policy improvements should focus on four key areas: equitable cost-sharing through carbon tax revenue redistribution, targeted support for breakthrough technologies (e.g., advanced photovoltaics), stable cross-party policy frameworks to ensure long-term investor confidence, and inclusive governance models that engage communities. Internationally, technology transfer and climate financing mechanisms must accelerate developing nations' transitions. Only through such comprehensive, balanced approaches can renewable energy systems fulfill their full potential in driving the global low-carbon transition.

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