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The Path Towards a Sustainable Future: A Critical Analysis of Renewable Energy Policies

Bahram Hosseinzadeh Samani[1], Kimia Taki[2]

[1] Professor of Mechanical Engineering of Biosystem, Shahrekord University, Iran
[2] Ph.D Candidate of Mechanical Engineering of Biosystem, Shahrekord University, Iran

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***Corresponding author email:**
b.hosseinzadehsamani@sku.ac.ir

ORCID:
0000-0002-8563-7080

Abstract

This article critically analyses global renewable energy policies through 2025. It focuses on eight countries: Germany, Denmark, China, the United States, India, Brazil, the UAE, and Morocco. The analysis highlights cross-country differences in renewable energy use, costs, reliability, and public attitudes. While renewable capacity has grown and costs have fallen, significant challenges remain. High-penetration renewable systems are becoming less reliable. Policy changes in the United States threaten further progress. Tariff wars have delayed billions of dollars in clean energy projects. Land-use conflicts are also intensifying globally. By 2050, demand for critical minerals is expected to rise sharply. This will exacerbate child labor, water scarcity, and geopolitical risks in the Global South. Meanwhile, the early phase-out of nuclear power in Germany and Denmark has increased fossil fuel dependence and raised consumer prices. These outcomes reveal the limitations of relying solely on renewables. Small modular reactors (SMRs) are already in use in Russia and China. They are considered a promising low-carbon addition to renewable energy systems. Commercial deployment of SMRs is expected in Canada, the United Kingdom, and other countries between 2026 and 2030. This paper argues that a rapid, cost-effective, and fair transition to net zero requires specific policy measures. These include long-term revenue certainty, responsible mineral management, biodiversity protection, nuclear integration, and community benefit-sharing. Without these measures, the energy transition will be slower, more expensive, and less equitable.

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1. Introduction

Over the past few decades, the international energy landscape has reached a critical juncture. Firstly, the planet is experiencing a rise in energy consumption, fueled by expanding populations, urban development, industrial growth, and greater electrification, particularly in emerging nations. Conversely, the ecological and climate repercussions of fossil fuel energy models have grown increasingly evident and concerning. The 2024 report indicates that fossil fuels accounted for 81.5% of the world's primary energy use, with energy-linked greenhouse gas emissions surpassing 40 gigatons of CO_2e (Institute, 2024).

Faced with the combined challenges of rising energy demand and the critical need to address climate change, numerous governments, organizations, and scientists have focused on renewable energy (RE) as a possible path toward a more sustainable, reliable, and fair energy future. Renewable energy typically denotes power derived from renewable sources such as sunlight, wind, moving water, geothermal heat, and organic biomass (Nations, 2023). These origins differ from those of fuels, as they are inexhaustible within human lifespans: so long as the sun shines, rivers run, or geothermal heat persists, their availability endures, rendering them inherently more sustainable. Furthermore, renewable energy technologies promise to transform not only how we generate electricity but also how we ensure energy security, promote economic development, and reduce environmental degradation (Agency, 2020).

The shift towards energy is frequently described as a comprehensive approach. The primary driver is to address climate change: substituting fossil fuels that emit levels of carbon with sources that produce low (or no) carbon emissions can greatly decrease greenhouse gases and contribute to controlling global warming and its related dangers, including severe weather, increasing sea levels, loss of biodiversity and challenges, to food and water availability among other impacts (Change, 2022). Aside from issues related to climate, renewable energy provides advantages for both the environment and public health since, in contrast to burning fossil fuels, the majority of energy systems do not release toxic air pollutants like sulfur oxides (SO_x), nitrogen oxides (NO_x) or particulate matter, which are linked to respiratory illnesses, environmental harm and acid rain (Agency, 2020; Change, 2022). People also use renewable energy for socio-political reasons. The price of making electricity from renewable sources has dropped a lot in the last 20 years. In some places, it is now more competitive with, and even cheaper than, electricity made from fossil fuels (I. R. E. Agency, 2024). Also, using more renewable energy can make energy security better and lower the need for imported fuels, which is very important for countries that don't have their own fossil fuel resources (I. R. E. Agency, 2024).

Third, the renewable energy sector could create jobs, such as making panels or wind turbines, installing them, keeping them in good shape, and providing other services for them. This could help both cities and rural areas grow their economies (I. R. E. Agency, 2024).

Lastly, by separating energy provision from reliance on fuel imports and volatile fossil-fuel markets, renewables could provide price stability and resilience against geopolitical disruptions (I. R. E. Agency, 2024). Nonetheless, the worldwide shift to energy is far from straightforward. The challenges related to technology, infrastructure, economy, and society are substantial. Renewable energy options like solar and wind are naturally variable; sunlight is not constant, and wind is not consistently present, leading to a mismatch between supply and demand (I. E. Agency, 2024d). Incorporating a proportion of these fluctuating renewable energy sources into current electrical grids necessitates major investments in upgrading grid energy storage solutions (such as batteries, hydropower, and hydrogen), demand-response strategies, and smart grid innovations (I. E. Agency, 2024d).

Moreover, the upfront costs of constructing energy facilities such as solar arrays, wind turbines, hydroelectric stations, and geothermal plants remain substantial, particularly in poorer nations and areas without sufficient financial resources or institutional support (Group, 2023). In addition to financial challenges, socio-political factors are also significant. In situations of opposition from local populations due to land-use disputes, environmental or visual impacts, or social disparities, these projects can be delayed or halted (I. R. E. Agency, 2024). Moreover, shifts to energy systems at the global level typically demand extensive policy frameworks, strategic long-term planning, and governance structures capable of balancing environmental objectives, energy security, economic growth, and social equity (Agency, 2021a). Given the tensions between optimistic projections and practical limitations, a meaningful assessment must evaluate both the promises and the pitfalls of renewable energy policies. This article undertakes such an assessment. The aim is not to dismiss renewable energy, but to understand it in a realistic and nuanced way. We conclude by suggesting how global energy policies can be rethought to navigate this transition more equitably, efficiently, and sustainably (Agency, 2021a).

The remainder of this paper is structured as follows. Section 2 presents a comparative analysis of renewable energy policies across eight countries: Germany, Denmark, China, the United States, India, Brazil, the UAE, and Morocco. For each case, we examine policy instruments, implementation history, measurable outcomes, and socio-economic implications. Section 3 critically evaluates common technical, economic, social, and political challenges, including intermittency, natural resource dependence, public acceptance, policy instability, and the complementary role of nuclear energy and small modular reactors (SMRs). Section 4 offers concrete policy recommendations to improve financial support, public awareness, infrastructure development, and international cooperation. Section 5 addresses two major criticisms of renewable energy (land-use conflicts and material sustainability) drawing on recent 2025 data. Section 6 concludes with key lessons for future policy-making and a call for balanced, technology-inclusive strategies.

2. Analysis of Renewable Energy Policies in Different Countries

2.1. Framework for Analysis

When thinking about renewable energy (RE) policies, there are a few things that are very important to keep in mind (Figure 1):

Policy tools and methods include tax breaks, feed-in tariffs (FiTs), subsidies, environmental rules, long-term plans, and making it easier to obtain a license.

History and implementation: When did these rules first come into effect, and how have they changed since then? What has been changed?

Outcomes and results: increasing the amount of renewable energy in the energy mix, making more electricity, creating jobs, cutting greenhouse gas emissions, making energy safer, and lowering the need to import energy.

Economic and social issues: costs for consumers or governments, stress on the grid and infrastructure, public acceptance, and effects on traditional job markets.

Transferability: Can these rules be used in other countries? What are the limits? This structure lets us examine and judge the policies of countries that prioritize leaders from the Global South, helping bring people from different parts of the world together.

This framework organizes policy assessment into five interconnected dimensions: (1) Policy tools and instruments (e.g., feed-in tariffs, tax incentives, auctions, subsidies); (2) Implementation history and timeline (policy start dates, amendments, and major revisions); (3) Measurable outcomes (renewable energy share, electricity generation, job creation, emissions reductions, energy security); (4) Economic and social implications (consumer costs, grid stress, public acceptance, employment transitions); and (5) Transferability (applicability to other national contexts and limitations). This structure enables systematic comparison of policy performance across both Global North and Global South countries.

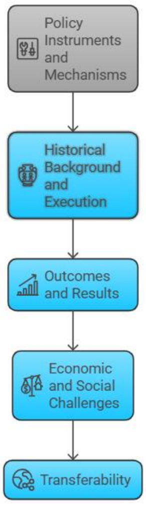

Figure 1. Analytical framework for evaluating renewable energy policies across countries.

2.2. Case Study: Germany

2.2.1. Policies and Instruments in Germany

The Renewable Energy Sources Act (EEG) in Germany has made the country a leader in energy law. This law set up feed-in tariffs (FiTs) to make sure that people who make renewable energy get a fair price for their work. This law has helped bring in money for solar, wind, biomass, and other types of renewable energy by giving people the peace of mind that they will always have a steady income (Action, 2023). The Energiewende (energy transition) policy, which began in the early 2010s, aims to eliminate nuclear power and fossil fuels while significantly increasing electricity generation from renewable sources (Energiewende, 2022). Germany has been moving toward a market-based system in the last few years. Instead of feed-in tariffs, it now uses auctions to find buyers for renewable energy projects. This makes prices more competitive (Systems, 2024). The government also supports renewable energy by funding infrastructure, grid upgrades, energy storage, and better grid integration (I. E. Agency, 2024d) (Figure 2).

2.2.2. Results and Successes in Germany

Due to these policies, the proportion of renewables in Germany's electricity generation has consistently grown, More than 50% by 2024 (G. E. Agency, 2025). Germany has effectively eliminated its energy dependence and is progressively reducing its reliance on imported fossil fuels. This transition has led to decreases in carbon emissions (G. E. Agency, 2025). In particular, the FiT scheme has played a role in fostering a robust local renewable energy sector, generating employment in manufacturing, installation, and maintenance (I. R. E. Agency, 2024). The German approach, focusing on long-range planning collaboration between the private sector and extensive policy structures, has been widely adopted by other nations as a benchmark (Agency, 2021a).

2.2.3. Challenges and Criticisms in Germany

Customers are very stressed out because networks are getting more expensive, which is a big problem. As more renewable energy sources, like solar and wind, come online, it is increasingly important to keep the grid stable and ensure supply and demand are in balance. This means storage and flexibility need to keep improving. The switch from fiat money to tenders in 2017 went well, and the changes since then have made it even better. Until 2025, concerns about competitiveness and energy security will worsen after nuclear power ends. This will mean that more goods will come from other countries and fewer goods will be made in the United States. These benefits will last for a long time (I. E. Agency, 2024f; Agency, 2023b; Group, 2023).

2.2.4. Why Germany Has Been Successful

Germany's achievements in the energy transition (Energiewende) can be attributed primarily to its comprehensive, enduring, and transparent policy framework (the EEG Act and the Energiewende Framework), which has created a reliable and foreseeable setting for both private investment and public involvement (G. E. Agency, 2025). By expanding its energy mix (wind, solar, biomass, hydroelectric, etc.) Germany has greatly reduced dependence on any one technology or weather pattern (I. R. E. Agency, 2025; China., 2025); this variety is especially crucial from a scientific standpoint on climate change, since the IPCC report highlights that fluctuations in renewable energy are a major obstacle to their incorporation into energy grids. That spatial and technological diversity is the optimal approach to mitigate this risk. The German public-private partnership model, with special support for citizen energy cooperatives and small producers alongside large companies, has contributed significantly to the widespread, socially accepted deployment of renewable energy projects (Agency, 2021a). Finally, extensive investment in critical infrastructure, including the expansion of transmission and distribution networks, energy storage, and flexibility mechanisms, has enabled the successful integration of a high share of renewable energy (over 54% of electricity consumption in 2024) into the country's energy mix (G. E. Agency, 2025).

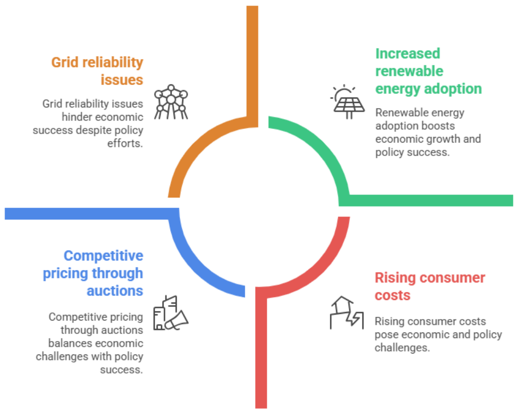

Figure 2. Germany's Transition Strategy.

2.3. Case Study: China

2.3.1. Policies and Instruments in China

China has enacted renewable energy strategies, with the authorities establishing bold goals for solar and wind power capacity. For years, the nation has led globally as the top investor in renewable energy infrastructure (I. E. Agency, 2024a). The government promotes energy through a mix of financial incentives, including subsidies, tax benefits, and feed-in tariffs, especially for wind and solar energy (Agency, 2023b). China has also established a National Renewable Energy Law that requires a growing share of renewable energy within the energy portfolio, while promoting technological advancement and facilitating market entry (Agency, 2023b) (Figure 3).

2.3.2. Results and Successes in China

China currently leads the world in manufacturing panels and wind turbines, boasting the greatest installed capacity for wind and solar energy, expected to surpass 1,400 GW by early 2025 (1,408 GW by the close of 2024) (I. R. E. Agency, 2025). The rapid growth of energy sources has contributed to lowering carbon intensity and broadening the energy portfolio, with renewables accounting for approximately 60% of installed electricity capacity by 2025 (59.1% as of September 2025) (China., 2025). The nation's extensive renewable energy initiatives have generated millions of jobs (7.4 million in 2023) and played a major role in advancing the green technology industry (I. E. Agency, 2024f).

2.3.3. Challenges and Criticisms in China

Although China has made progress in renewable energy, it continues to depend substantially on coal for power production, and moving away from fossil fuels remains a significant obstacle (I. E. Agency, 2024a). Incorporating extensive renewable energy resources into China's national grid has created considerable challenges for stability and operational efficiency (I. E. Agency, 2024a). The nations' renewable energy strategies are highly centralized and frequently change, creating uncertainty for investors (Agency, 2023b).

2.3.4. Why China Has Been Successful

China's achievements in energy stem from robust governmental backing, substantial investments (accounting for over 80% of worldwide investment in manufacturing technologies), and the leveraging of its leading manufacturing capabilities (including

88% of global solar cell capacity) (I. E. Agency, 2024f). The government has employed a down-to-earth strategy to drive expansion by defining specific goals (like 1,200 GW of wind and solar by 2030) and offering financial incentives to both domestic and international investors (I. R. E. Agency, 2025). The huge market size and growing electricity demand (adding 64% of global capacity by 2024) provide a solid foundation for the scalability of renewable projects (I. R. E. Agency, 2025).

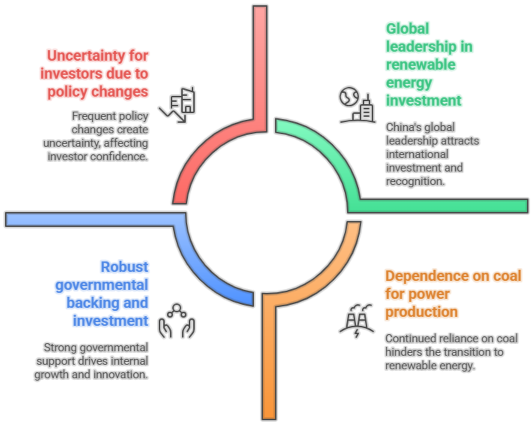

Figure 3. China's renewable energy landscape.

2.4. Case Study: Denmark

2.4.1. Policies and Instruments in Denmark

Denmark stands as a world frontrunner in offshore wind power. With strategies focused on clean energy and achieving fossil-free status by 2050, it aims to produce over 74% of its electricity from wind and solar sources by 2025 (D. E. Agency, 2024b). Since the 1980s, the Danish government has introduced feed-in tariffs (FiTs) and tax benefits (including carbon taxes and accelerated green depreciation). Established long-term goals (achieving 100% renewable energy by 2050, as per the 2018 agreement) to promote the shift to renewable energy (Agency, 2023c). The nation has also advanced grid technologies and enhanced cross-border electricity connections (including 6 subsea links and surplus capacity trading) to maintain energy sustainability despite a substantial share of VRE (88.4% in 2024) (I. E. Agency, 2024e) (Figure 4).

2.4.2. Results and Successes in Denmark

Denmark produces a share of its electricity from wind power, with wind accounting for more than 50% of the nation's electricity usage in 2024, and wind combined with solar meeting more than 60% of total demand (Association, 2024). The Danish approach has successfully reduced CO_2 emissions while maintaining a stable, competitive energy market. The wind energy industry has spurred innovation, developed technologies, and boosted international competitiveness (Association, 2024).

2.4.3. Challenges and Criticisms in Denmark

Denmark faces challenges balancing wind energy variability and maintaining grid stability, underscoring the need for border links and innovative technologies that do not rely heavily on fossil fuels (such as gas in CHP) during low production periods. Although the renewable energy sector has expanded, the nation continues to fulfill a portion of its energy demand through imports (gas and oil). It remains susceptible to changes in global markets. The cost of transitioning to renewable energy has led to higher energy costs for consumers. Sparked worries about energy poverty, particularly given that green electricity is taxed more heavily than fossil fuels like petrol and natural gas (D. E. Agency, 2024a). The prohibition on building power plants since 1985 (with no existing plants prior) has worsened these problems and heightened reliance on imports and renewable sources. However, there is consideration to lift this ban in 2025.

2.4.4. Why Denmark Has Been Successful

Denmark's focus on innovation and technological development in the wind industry has enabled it to become a global leader in wind turbine manufacturing (Association, 2024). Strong governmental support, clear long-term energy goals, and an open market for renewable technologies have fostered a competitive and sustainable industry (Agency, 2023c).

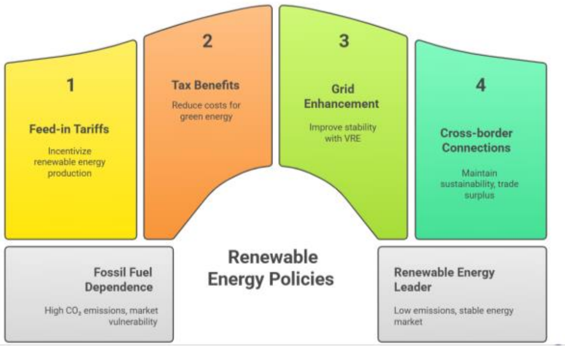

Figure 4. Denmark's renewable energy transition.

2.5. Case Study: United States

2.5.1. Policies and Instruments in the United States

There are policies in place at both the federal and state levels in the U.S. that work together to promote renewable energy. The Investment Tax Credit (ITC) and the Production Tax Credit (PTC) in the Inflation Reduction Act (IRA) of 2022 provide a 30% tax break for solar and wind installations. Twenty-nine states have also passed Renewable Portfolio Standards (RPS). These standards tell utilities what they need to do to make renewable energy. The IRA framework is mostly about tax breaks, funding for infrastructure, and bonuses for using clean energy. The One Big Beautiful Bill Act (OBBBA) changed the law in 2025. In July 2021, the bill became law. It set deadlines for some wind and solar credits to end after 2027, made the rules for domestic content stricter, and placed limits on foreign entities of concern (FEOC) to prevent some international suppliers from becoming too involved. In some cases, tariffs on solar panels from Southeast Asia and other regions rose by as much as 50%. Some programs that sent money to rural areas, such as the Rural Energy for America Program (REAP), which had given out $911 million before the changes, were also put on hold (Energy, 2024a) (Agency, 2021b) (Agency, 2023a) (Figure 5).

2.5.2. Results and Successes in the United States

The United States has experienced growth in renewable energy capacity, especially in wind and solar sectors (with over 100 GW installed by 2024), with renewables representing roughly 30% of total electricity production by 2025 (Administration, 2025). Expansion in the energy field has generated many employment opportunities (3.6 million clean energy jobs by 2024, including 370,000 solar positions and upwards of 125,000 wind roles) (Energy, 2024b). Federal and state incentives (including the ITC/PTC under the IRA and RPS mandates, in 29 states) have stimulated innovation and investment (exceeding $300 billion) in energy technologies by 2025 (Laboratory, 2024).

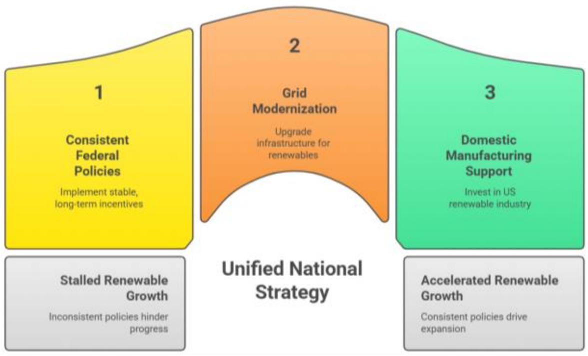

Figure 5. Accelerating renewable energy in the U.S.

2.5.3. Challenges and Criticisms in the United States

Policies at the federal and state levels differ, making it hard for renewable energy to move forward. For instance, 29 states have RPS, while others prioritize fossil fuels. The changes to the OBBBA in 2025, which included ending some tax credits based on foreign content and raising tariffs on solar imports from Southeast Asia by up to 50%, have been linked to a 36% drop in investments in the first half of the year and the cancellation of about $8 billion in projects. It is hard to connect wind and solar power to the grid because the voltage changes and there are more than 1,000 GW of interconnection queues. These things, along with the fact that 80% of the world's solar panels come from China, have slowed down the return of manufacturing in the United States (I. E. Agency, 2024g; Agency, 2021b) (I. E. Agency, 2024c; Future, 2025).

2.5.4. Reasons Behind the Difficulties Encountered by the United States

The United States has achieved a 25% share of electricity from renewables in 2025, primarily from wind and solar, yet fossil fuels continue to dominate primary energy (84%) and electricity generation (75%). Progress is shaped by regional variations, with higher public support in the Northeast (69%) than in the Great Plains (55%), and by policy frameworks that differ by state—RPS in 29 states versus a fossil-fuel emphasis in the South. The 2025 policy adjustments, including tariffs up to 49% on certain solar imports, have added costs (up to $0.10/W) and contributed to an estimated 62,000 job losses in the sector, while renewables occupy less than 74.5 million acres of land (predominantly for biofuels) (I. E. Agency, 2024g).

2.6. Case Study: India

2.6.1. Policies and Instruments in India

India's advancements in energy are propelled by the National Solar Mission (initiated in 2010) and the ambitious goals set within the Nationally Determined Contributions (NDCs) for COP26, which include a target of 500 GW of non-fossil energy capacity (encompassing hydro and nuclear) by 2030, with half of this (259 GW) attained by 2025 (Development, 2025). Major mechanisms consist of the Linked Production Incentive (PLI) program for in-country production (featuring 48.3 GW of PV module capacity allocated and a budget of Rs 24,000 crore) renewable purchase obligations (RPOs/RCOs) rising to 43.33% by 2029-30 (up from 29.91% in 2024-25) and the Gap Finance Facility (VGF) for Battery Energy Storage Systems (BESS) offering aid covering, up to 40% of capital expenditure for 30 GWh by 2030 (Development, 2025) (Figure 6).

2.6.2. Results and Successes in India

The NED surpassed 250 GW of fossil energy capacity in 2025 and currently (as of June 2025) stands at 242.8 GW (50.07% of overall power capacity), placing third worldwide in solar (119.02 GW) and fourth in wind (52.14 GW). During (Arias, Moreira, & Feijoo, 2025) FY 2024-25 an unprecedented 29.52 GW of energy capacity was introduced (primarily between 21-23.83 GW of solar twice the amount of the prior year) driven by programs like PM-KUSUM (featuring more than 10 lakh solar pumps and 640.99 MW installed) positioning India as the frontrunner among developing nations, in solar and wind capacity growth (exceeding 20 GW in the initial half of 2025) (Company, 2025).

2.6.3. Challenges and Criticisms in India

Although advances have been made, reliance on coal continues to account for 73–79% of power production. The grid integration of the 60 GW renewable capacity milestone has been postponed due to insufficient transmission infrastructure and policy irregularities (including DISCOM financial deficits and recent funding instability), which are obstructing financing (I. E. Agency, 2025b). Land acquisition and social consequences (such as the loss of community livelihoods and protests at sites such as Pavagada) for large solar parks remain contentious (I. E. Agency, 2025b).

2.6.4. Why India Has Been Successful

India's success stems from policy reforms, international partnerships, and the leveraging of its solar potential, though scaling to 500 GW requires addressing fossil fuel lock-in (Development, 2025).

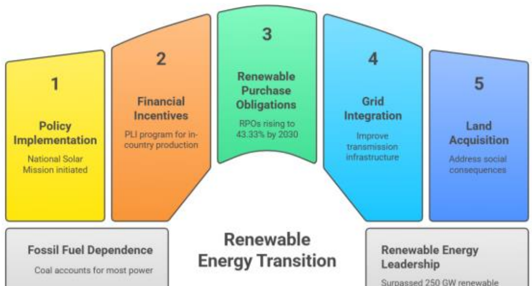

Figure 6. Achieving India's renewable energy goals.

2.7. Case Study: Brazil

2.7.1. Policies and Instruments in Brazil

Brazil's energy mix is set to reach 50% renewable in 2024, with hydro (56% of electricity) and biofuels leading the way through RENOVABIO (reducing 50 million tons of CO_2e) and the National Biofuels Program (ProBio); the Future Fuel Law (14993/2024) promotes sustainable aviation fuel (SAF) and green diesel, while the biodiesel mix is set to increase to 15% from August 2025. The 16% target by March 2026 may be delayed (I. E. Agency, 2025a) (WSP, 2025) (Figure 7).

2.7.2. Results and Successes in Brazil

As the world's second-largest ethanol producer (after the United States, with 29 billion liters in 2024), Brazil's biofuels have reduced emissions (39% lower than fossil fuels) and strengthened energy security (45% reduction in dependence on gasoline imports). Hydro and biomass dominate, with renewables accounting for 50% of the energy mix by 2024 (Empresa de Pesquisa Energética, 2020).

2.7.3. Challenges and Criticisms in Brazil

Deforestation risk from biofuel expansion (16% higher CO_2 emissions due to soy and sugarcane land-use change) and hydro volatility due to droughts (10% production reduction in 2024) are key issues. Policy delays in biodiesel blending (postponement from March to August 2025) highlight implementation gaps (Bioenergy, 2024).

2.7.4. Why Brazil Has Been Successful

Strong biofuel (RENOVABIO) and natural resource (sugar/biomass) policies have driven success, but diversification beyond hydro (towards wind/solar with 23.7% of electricity in 2024) is essential for resilience (I. E. Agency, 2025a).

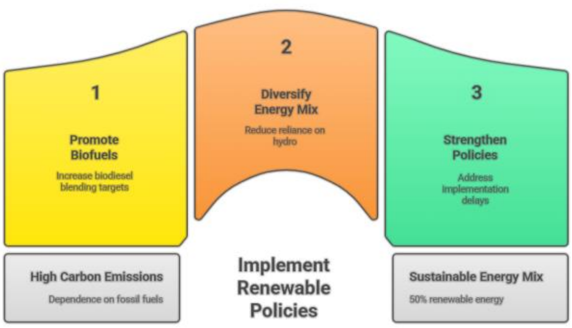

Figure 7. Brazil's renewable energy transition.

2.8. Case Study: United Arab Emirates (UAE)

2.8.1. Policies and Instruments in the UAE

The UAE Energy Strategy 2050 sets a target of generating 50% of energy from clean sources (renewables, nuclear, and other clean sources) by 2050. It includes tripling renewable capacity to 14 GW by 2030 and investing AED 150–200 billion. The strategy is being implemented through low-cost competitive tenders (DEWA), policy incentives, green bonds (such as Dubai's $2 billion issuance in 2024), and public–private partnerships (PPPs) at the Mohammed bin Rashid Al Maktoum Solar Park (Masdar, 2025) (Figure 8).

2.8.2. Results and Successes in the UAE

The Mohammed bin Rashid Al Maktoum Solar Park is set to reach 3.86 GW by the end of 2025. The 24/7 Solar + Battery Storage project (Masdar and EWEC in Abu Dhabi) represents an innovation in providing continuous clean electricity. The UAE is a leader in green hydrogen pilots (the first green hydrogen industrial plant in the region, the Masdar–EMSTEEL project for green steel, and a target of producing 1.5 million tonnes of low-carbon hydrogen annually by 2031) (Masdar, 2025).

2.8.3. Challenges and Criticisms in UAE

Very high initial costs (around $163 billion by 2050) and heavy dependence on oil and gas (72% of electricity generation in 2023) continue to limit the pace of transition. However, diversification has accelerated significantly since 2019 (CNN, 2025).

2.8.4. Why the UAE Has Been Successful

Visionary planning (Energy Strategy 2050), smart use of oil revenues to finance large projects, and a successful public-private partnership model have enabled rapid scalability; this model is fully transferable and replicable for other Gulf countries (including Saudi Arabia and Oman) (Masdar, 2025).

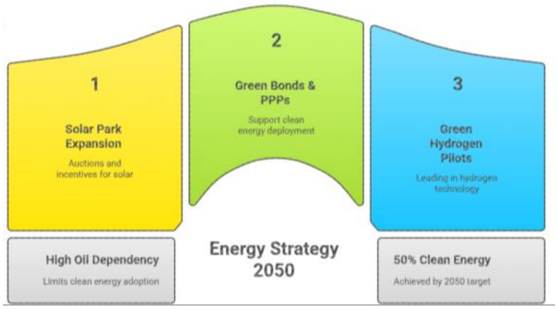

Figure 8. UAE's transition to clean energy.

2.9. Case Study: Morocco

2.9.1. Policies and Instruments in Morocco

Morocco's energy strategy sets a target of a 52% share of renewable electricity by 2030 and includes increasing capacity to over 15 GW (wind, solar and hydro); this will be supported by the Noor Ouarzazate solar complex (with a capacity of 580 MW), competitive tendering (such as two 241-hectare solar projects in Khouribga by MASEN), and grid upgrades and storage (batteries) to manage variability. The coal phase-out by 2040 (with the retirement of existing plants and no new development, without international support until the late 2040s) is consistent with the Powering Past Coal Alliance (PPCA, accession 2023) commitments and the new Paris NDC, with coal accounting for 59.3% of electricity generation in 2024 (Circle, 2025) (Figure 9).

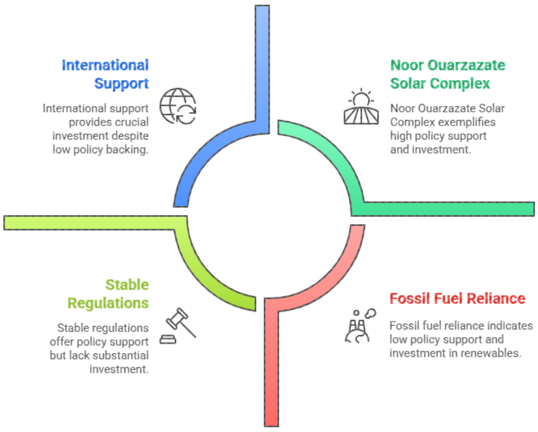

Figure 9. Morocco's renewable energy success factors.

2.9.2. Results and Successes in Morocco

Renewables are set to reach around 40% of electricity capacity by 2025 (up from 9% in 2015 to nearly 25% last year), attracting over $5.3 billion in investment; the Noor Ouarzazate complex (one of the largest in the world) will power 2 million people, offset 700,000 tons of CO_2 annually, train African engineers, and demonstrate a model for the coexistence of solar, wind, and hydropower in the national grid (South, 2025).

2.9.3. Challenges and Criticisms in Morocco

Continued dependence on fossil fuels (59.3% coal and imported gas) and the need for extensive financing (for coal phase-out and storage) remain challenging. However, international support (such as JETPs and PPCA technical assistance) is accelerating progress and reducing dependence on fossil fuel imports in volatile global markets (Circle, 2025).

2.9.4. Why Morocco Has Been Successful in Morocco

Regulatory stability, public-private partnerships (PPPs) through MASEN, and long-term planning (such as NDC and PPCA) have made Morocco a continental model for Africa (with a focus on vision, clarity, and commitment), enabling transformation in a continent with policy inconsistencies (South, 2025).

2.10. Comparison and Analysis: Why Some Countries Have Been More Successful

Countries that have been more successful in renewable energy development typically combine long-term policy stability, financial support mechanisms, grid flexibility, and public-private partnerships (Agency, 2021a). Diversity of renewable sources reduces risks and ensures the stability of energy production, making the system more resilient to external shocks (e.g., weather variations, market fluctuations) (Agency, 2023c). Political stability and consistent incentives are critical to creating a sustainable, competitive renewable energy sector (Agency, 2021a). Challenges related to integration, costs, and public acceptance must be continuously addressed to maintain progress (I. E. Agency, 2024d). Global South leaders such as India and Brazil highlight scalable models for emerging economies, though fossil fuel dependencies persist (Table 1).

Table 1. Comparison and analysis of energy policies of different. countries.

Factor/Country	Strong Financial Support	RE Share 2024	Renewable Energy Diversity	Public/Private Participation	Policy Stability	Challenges
Germany	(EEG + FiT)	59.4%	(Solar, Wind, Biomass)	(Citizens + Companies)	Relatively High	Consumer Cost, Grid Pressure, Nuclear Phase-Out (I. E. Agency, 2024b)
China	(Government Subsidies)	32.0%	(Wind, Solar, Biomass)	(State + Private)	Moderate	Infrastructure Needs, Coal Dependency (I. E. Agency, 2024a)
Denmark	(Wind Incentives)	88.4%	(Wind Dominance)	Private + Public	High	Energy Imbalances, Import Reliance, Nuclear Exit (Bech-Bruun, 2025)
United States	Mixed (State + Federal)	24.0%	(Wind, Solar)	Strong Private Sector	Unstable (2025 Cuts)	Political Fragmentation, Tariffs on Imports (I. E. Agency, 2024g) (Agency, 2021b)
India	(PLI, RPOs)	33.2%	(Solar, Wind, Hydro)	Public-Private	Moderate	Coal Lock-In, Land Conflicts
Brazil	(Biofuels Incentives)	88.2%	(Hydro, Bioethanol)	Strong Agribusiness	High	Deforestation Risks
UAE	(Green Bonds)	27.8%	(Solar, Hydrogen)	PPPs	High	Oil Dependency (Masdar, 2025)
Morocco	(Auctions)	26.5%	(Solar, Wind)	International PPPs	High	Fossil Reliance (South, 2025)

2.11. Common Challenges, Critical Lessons, and Future Policy Directions

Even leading countries face complex barriers that make renewable energy transitions costly and slow. Upfront infrastructure costs, heavy subsidy needs, and potential consumer price increases strain governments and households. The variability of solar and wind forces major investments in storage, smart grids, and grid reinforcement. Socially, benefits often reach wealthier regions first, while low-income groups face higher bills and workers in fossil-fuel industries risk job losses without retraining programs. Politically, sudden subsidy cuts or regulatory instability erode investor confidence and delay climate goals.

It is therefore essential not to be misled by success statistics alone. A critical analysis reveals hidden costs and inequalities that, if ignored, undermine the entire transition. What appears as a short-term victory may later become environmental debt, deeper class divides, or new dependencies on scarce minerals and vulnerable supply chains. Marginalized communities, villages, and low-income households either face higher energy bills or gain no access to clean energy benefits.

Many countries' infrastructure and markets are not yet ready for widespread renewable adoption. Not every region has steady sun, wind, or access to lithium, cobalt, and copper. Imposing a single model across different geographies and economies is inefficient and can cause further environmental degradation and new dependencies. Multi-hundred-billion-dollar investments rely on generous subsidies and long-term political commitments. A sudden government change or budget cut can leave behind half-finished projects and bankruptcies. Moreover, wealthy Global North models—built on privileged financial, technological, and political positions—cannot be copied directly by Global South countries struggling with foreign debt, weak infrastructure, corruption, and instability. Without understanding these differences, promoting one model deepens North–South inequality.

From these experiences, six clear lessons emerge for future policymaking:

Long-term, stable, transparent policy is essential. Investors need confidence that rules will not change fundamentally for decades. Volatility causes capital flight and halts progress.

Diversifying renewable portfolios (solar, onshore/offshore wind, geothermal, biomass, green hydrogen) increases flexibility, resilience, and reduces dependence on any single source.

Genuine government–private sector cooperation combines resources and expertise, ensuring benefits (jobs, lower costs) are distributed more fairly across society.

Policy stability is the beating heart of the transition. Sudden shocks—as seen in Germany and Denmark after hasty nuclear phase-outs—can set back progress for years and impose high economic and environmental costs.

Continuous critical analysis of social, economic, and environmental consequences is necessary. Policymakers must constantly ask: Who benefits? Where are hidden costs? Are solutions applicable to all regions and social groups?

Completely abandoning controllable low-carbon sources (e.g., new-generation nuclear, small modular reactors) has often been a strategic mistake. Countries that phased out nuclear after Fukushima faced baseload gaps, burned more coal and gas, and delayed climate goals. A smart mix of renewables with stable, controllable low-carbon sources offers a faster, more realistic path to net zero.

A successful energy transition is therefore measured not only in reduced carbon emissions, but also in social justice, economic sustainability, and global enforceability. It will not be achieved by slogans and haste, but by stable policies, technological diversity, inclusive cooperation, relentless critical analysis, and a smart mix of all low-carbon options.

3. Critical Analysis of Renewable Energy Policies

In this section, we provide a critical and analytical assessment of the existing renewable energy policies across different countries. While renewable energy initiatives have largely been seen as beneficial for mitigating climate change and advancing energy security, they come with both successes and challenges. This analysis will delve into areas where policies have succeeded and, equally, where they have faced obstacles, particularly in terms of technical and economic challenges, dependence on natural resources, social and cultural impacts, policy instability, and the underexplored role of nuclear complements.

3.1. Technical and Economic Challenges

The transition to renewable energy, while full of inspiring promise, is fraught with profound technical and economic hurdles that even leading countries face. Many governments have set ambitious targets for increasing the share of renewables. Still, the deployment and integration of these technologies often come at astronomical costs, especially in the early stages when upfront investments such as installing solar panels, wind turbines, and storage systems put a strain on government budgets or the willingness of private investors. One of the biggest hurdles is the huge upfront costs of installing renewable infrastructure, which can be a nightmare for developing countries or regions with limited access to finance. In these circumstances, the initial capital required can exceed public budgets or investor tolerance, especially when financial incentives are inconsistent and unpredictable. The International Renewable Energy Agency (IRENA) 's Renewable Energy Policy for Cities reports show that cities, as major energy consumers, play a key role in this transition. Still, without strong supporting policies, these costs can hinder progress and exacerbate urban inequalities (I. E. Agency, 2024d).

In general, renewable energy systems cost less to run over their lifetime than fossil fuels, but they still cost a lot of money to keep going. For instance, projects might not make as much money if they have to keep wind farms running during bad weather or pay a lot for large battery storage, which is still a major problem with the technology. The International Energy Agency (IEA) said in a 2024 report that, even though renewable energy sources have grown significantly, they won't be able to fully meet global goals like tripling capacity by 2030 due to high maintenance costs and challenges with system integration. When solar and wind power aren't always available, it's hard to keep the power system stable and balanced. We need to fix the old networks, build smart grids, and add storage systems to handle these new resources so the power stays on and works right. It's easy to see that these kinds of problems happen a lot in Germany.

More than 54% of its electricity will come from renewable sources by 2024. It is less stable because it has to stop using nuclear power and get more electricity from other countries. One of the most expensive problems in the country is still figuring out how to balance the number of people who want things with the number of things available. The International Energy Agency's 2025 Energy Policy Review of Germany says that to fix these problems, the grid needs to work more effectively and energy prices need to fall to ensure the transition is safe and affordable (I. E. Agency, 2024b).

These problems with money and technology not only make the transition take longer, but if they aren't carefully planned for, they could also make problems with people and the environment worse. This road will only work if we have rules that last, ideas that change, and countries that work together.

3.2. Dependency on Natural Resources

One of the fundamental limitations of renewable energy, often overlooked in public discussions, is its strong geographic dependence. Not all parts of the world are equally suitable for all types of clean energy, and this fact makes the idea of a "one-size-fits-all" solution practically impossible. Solar energy is incredibly efficient in areas with high solar radiation, such as sub-Saharan Africa, the Middle East, or the American Southwest. Still, in countries such as Germany, Norway, or Canada, which are located at high latitudes and are cloudy or dark for a large part of the year, the efficiency of solar panels drops sharply.

Germany is a classic example: despite massive investment in solar (over 90 GW of installed capacity by 2025), its average effective capacity factor is less than 12%, whereas the same figure in Australia or the sunny desert of Saudi Arabia can exceed 27% (I. E. Agency, 2024d). This geographical difference not only increases the cost per kilowatt-hour but also causes a large portion of investment to be spent in areas that are not naturally optimal for that technology.

Wind energy has a similar story: offshore turbines in the North Sea or on the east coast of China perform exceptionally well, but in many landlocked or windless countries they are practically uneconomical (I. E. Agency, 2024d). Hydroelectricity can only be justified in areas with suitable topography and constant water flow, and more than 60 percent of its global potential is currently either unused or blocked for environmental and social reasons (I. E. Agency, 2024d).

In addition to geographical constraints, resource management and environmental side effects also pose major challenges. Large hydroelectric dams, while seemingly clean, often completely transform river ecosystems, blocking fish migration routes, trapping sediments, and in cases such as the Three Gorges Dam in China or the Amazon projects, displacing tens of thousands of people

(Agency, 2020). In many countries, social and environmental resistance has almost halted the construction of new dams (Agency, 2020). Bioenergy, once promoted as a green alternative to fossil fuels, is also facing serious criticism: the extensive cultivation of energy crops (such as corn for ethanol or palm oil for biodiesel) directly competes with agricultural land, raises food prices, and in cases such as Indonesia and Malaysia, has led to widespread deforestation (Agency, 2020). Even burning forest waste or wood, if done unsustainably, can increase carbon emissions in the first few decades until new trees grow (Agency, 2020).

Thus, any renewable option that at first glance seems absolutely "clean" comes with serious geographical, environmental or social limitations in practice. The result is that no country can achieve full sustainability by relying solely on classic renewables (solar, wind, hydro); instead, a smart, regionally based mix, and sometimes the use of complementary low-carbon sources (such as new-generation nuclear, geothermal, or even gas with carbon capture), becomes inevitable. Ignoring these real limitations is the biggest mistake seen in many national and international climate plans today.

3.3. Social and Cultural Impacts

In different parts of the world, people have very different levels of acceptance of renewable energy technologies. This shows how important it is to look more closely at how clean energy policies affect people to make sure the change is fair. Some groups and places have chosen to use renewable energy to help the environment, make jobs, and make energy safer. Some people have fought against it, though, because they don't like how it looks (like wind farms ruining the natural landscape) or how it changes their lives (like hydropower projects moving people). A lot of the time, renewable energy projects go against how people used to live and what they believed in. This is especially true in the country, where people might think that big wind or solar farms are strange and get in the way of their lives (I. R. E. Agency, 2024). Recent policy discussions in Denmark have shown that the public there doesn't want more renewable energy (I. R. E. Agency, 2024). Also, moving from fossil fuels to renewable energy may mean fewer jobs in the energy sector. This change can really hurt the economy in places where coal or oil is a major part of the economy.

People who work with fossil fuels can't switch to renewable energy because they don't have the right skills or programs to learn new ones. This can make people less likely to support politicians and policies that support clean energy. For instance, mine closures have had a big effect on the economy in some U.S. communities that rely on coal. This has made them less likely to support policies that promote cleaner alternatives (I. E. Agency, 2024g). If we don't plan carefully for these changes in society and the economy, the switch to cleaner energy could make things worse by making people less willing to accept it and deepening inequalities.

3.4. Unstable Policy Frameworks

Many governments have enacted strong policies to encourage the use of renewable energy, but policy instability remains a major obstacle that could make the transition to renewable energy less successful in the long run.

Policies that are only in effect for a short time: Policies that only last for a short time are common in government, and they can make the market less stable. For instance, the government might offer tax breaks or subsidies for a few years, but if the economy worsens or the government changes, they might be cut back or eliminated. Investors and developers who need clear, long-term commitments to finance renewable energy projects find it hard to work in this unstable environment. Different governments have made major changes to energy policies in the U.S. and other countries. This has changed what renewable energy programs want to do and what they are working on.

Unintended negative effects: Some renewable energy policies may have unintended negative effects in the short term.

For instance, it's hard to guess how much wind and solar power will cost because China changes its rules so often. Too much focus on market-based methods: Countries like the U.S. and Germany have switched from feed-in tariffs (FiTs) to auctions. This has made it more like a market for putting up renewable energy. This change has made the market more competitive and lowered the price of renewable energy. For example, the most recent German auctions for onshore wind and solar on buildings had record amounts (6.5 GW for wind in 2023) and bids that were too high (378 MW for 263 MW solar target), but the average prices were lower (7.34 ct/kWh for wind and 8.92 ct/kWh for solar). However, this can make the market less stable for smaller developers and harder for community- or area-based projects to get off the ground.

3.5. The Role of Nuclear Energy in Complementing Renewables

Although energy transition narratives are largely focused on renewables, nuclear power, especially small modular reactors (SMRs), can play a very effective complementary role to intermittent wind and solar sources as a low-carbon baseload and dispatchable power source. Due to their smaller size, greater flexibility in location, and shorter construction time, SMRs can contribute to grid stability in systems with a high share of renewables (WSP, 2025).

In Europe, interest in SMRs is growing rapidly. Sweden, Poland, Estonia, and the Czech Republic are just some of the countries that have said they will use SMRs by the middle of the 2030s. The main goal is to replace old coal-fired power plants and make low-carbon industrial heat and green hydrogen (O. N. E. Agency, 2025) (WSP, 2025). This technology offers a significant opportunity for decarbonization, especially for energy-intensive sectors that require a continuous and stable energy supply (O. N. E. Agency, 2025).
But there are still a lot of problems with making SMRs. Some of these are complicated rules, the need for safety standards to be the same everywhere, concerns about how to handle nuclear waste, and a shortage of skilled workers (Wavestone, 2025). Some European countries are still trying to get rid of nuclear power completely. This could stop this technology from being fully used as a backup for renewable energy sources (Solutions, 2025; Wavestone, 2025).

Finally, experts say that for a strong and realistic energy transition, policymakers shouldn't rely too much on variable renewable sources that lack sufficient fixed and flexible capacity. They should instead plan for the long term by using a good mix of renewable and nuclear sources, especially SMRs (O. N. E. Agency, 2025).

3.5.1. Small Modular Reactors (SMRs): A Balanced Assessment of Pros and Cons

Given the paper's proposal that SMRs can complement intermittent renewables, a balanced assessment of their advantages and limitations is necessary.

Advantages of SMRs. SMRs offer several potential benefits over traditional large-scale nuclear reactors. First, they require lower upfront capital costs, making them more accessible to a wider range of investors and countries (WSP, 2025). Second, they promise shorter construction timelines (theoretically 3 to 5 years compared to a decade or more for conventional plants) which aligns better with urgent climate targets (WSP, 2025). Third, SMRs provide flexible siting options, including repurposing decommissioned coal plant sites, thereby utilizing existing infrastructure and grid connections (O. N. E. Agency, 2025). Fourth, as a dispatchable low-carbon power source, SMRs can supply stable baseload electricity that effectively complements the variability of wind and solar generation (O. N. E. Agency, 2025).

Disadvantages and Challenges. However, significant barriers remain. On the regulatory front, existing nuclear licensing frameworks were designed for large, site-built reactors and are not well-suited for modular or advanced designs. Regulatory harmonization across borders is lacking, creating uncertainty for manufacturers and operators (Wavestone, 2025). Public acceptance poses another major hurdle. Countries with strong anti-nuclear histories (such as Denmark, which banned nuclear power plants in 1985 and is only reconsidering this ban in 2025) present significant political and social opposition to any new nuclear deployment, including SMRs (Bech-Bruun, 2025). Even in countries open to nuclear energy, local communities often resist siting due to safety concerns, fears about waste transport, and distrust of operators (Bech-Bruun, 2025).

Furthermore, SMRs do not solve the longstanding problem of radioactive waste disposal, which remains an unresolved challenge (Bech-Bruun, 2025). A shortage of skilled workforce and immature supply chains also hinder rapid deployment (Solutions, 2025; Wavestone, 2025). Finally, it must be noted that SMRs remain commercially unproven at scale; first deployments are expected only between 2026 and 2030 in countries such as Canada and the UK, meaning their real-world performance and costs are still uncertain (see abstract).

Implications for Policy. For SMRs to fulfill their promise as a complement to renewables, policymakers must simultaneously address regulatory reform, public engagement, workforce development, and waste management. Without progress on these fronts, SMRs risk becoming another incomplete solution rather than a bridge to a fully decarbonized grid (O. N. E. Agency, 2025; Solutions, 2025).

3.6. Conclusion: Addressing the Challenges

Policies that promote renewable energy have led to cleaner, longer-lasting energy systems. But we still need to figure out how to fix the problems raised before, including those related to technology, the economy, society, and the law. We need to think about more than just new technologies and ways to save money when we switch to a new energy source. We also need to think about how the change will affect people, such as how it will get people involved, create jobs, and be fair. People and businesses need to know what the government wants from them. The government needs to make rules that are clear, consistent, and stay in place for a long time for this to happen. They also need to make sure that everyone involved agrees with the change and that it is fair. Also, policies that can be changed and added to are important for keeping up with the fast-changing field of renewable energy. This change will help ensure it benefits many people and that the good things last for a long time. Nuclear power could help by making it less likely to happen all the time (Agency, 2021a) (Solutions, 2025).

3.7. Nuclear Energy's Own Challenges: Waste, Accident Risk, and Long Construction Times

While the preceding sections argue that a premature nuclear phase-out in Germany and Denmark has complicated the renewable transition, a balanced critical analysis requires acknowledging the significant challenges inherent to nuclear power itself. These challenges (radioactive waste disposal, accident risk and public perception, and chronic construction delays) cannot be overlooked when assessing nuclear's role as a complement to renewables.

3.7.1. Radioactive Waste Disposal: An Unresolved Legacy

No country has yet achieved permanent geological disposal of high-level nuclear waste. Germany, presented in this paper as a case of hasty nuclear phase-out, faces its own serious waste disposal problems. The Konrad repository (intended for low- and intermediate-level waste) has faced continuous delays, with project managers admitting that completion on schedule is "no longer achievable" (Bech-Bruun, 2025; Solutions, 2025). Even Small Modular Reactors (SMRs), promoted in this paper as a promising low-carbon addition, do not eliminate the waste problem. Policy discussions in Denmark indicate that even with a potential move toward SMRs, radioactive waste management remains an open and unresolved challenge (Bech-Bruun, 2025).

3.7.2. Accident Risk and Public Perception

The Fukushima Daiichi accident (2011) fundamentally reshaped global nuclear policy and directly triggered Germany's phase-out decision (as noted in section 2.2.3 of this paper). However, public response was not irrational: the accident caused widespread contamination, forced mass evacuations, and left lasting psychological trauma. Research on residents near Fukushima's interim storage facilities found that years after the accident, a significant percentage still distrusted information from public authorities and remained concerned about offspring effects from radiation exposure (D. E. Agency, 2024a). These findings highlight that the psychological and social dimensions of nuclear risk (including trust in institutions and feelings of involuntary exposure) are legitimate factors in democratic policymaking. Any argument for nuclear expansion must grapple seriously with public opposition (D. E. Agency, 2024a).

3.7.3. Chronic Construction Delays and Cost Overruns

Perhaps the most damning empirical challenge to nuclear energy as a timely climate solution is its poor project delivery record. The IEA's 2025 report notes that "experience from Western countries shows that the total cost of building a nuclear power plant exceeds initial estimates by between two and even five times" (I. E. Agency, 2025b). The paper itself, in section 3.5, acknowledges high construction costs for SMRs and a shortage of skilled workers as major challenges (Solutions, 2025; Wavestone, 2025). Furthermore, nuclear plant construction typically takes more than a decade, while climate targets for the 2030s require much faster carbon emission reductions (WSP, 2025). This means that even if SMRs achieve commercial deployment in Canada, the UK, and other countries between 2026 and 2030 (as stated in the paper's abstract), they cannot rapidly solve the immediate intermittency challenges of renewables being deployed today.

3.7.4. Toward a Balanced Conclusion

None of the above invalidates the paper's core argument: that Germany and Denmark's hasty nuclear phase-outs, without adequate replacement of baseload capacity, increased fossil fuel dependence and consumer prices (D. E. Agency, 2024a; I. E. Agency, 2024b; Agency, 2023b; Group, 2023). However, it does suggest that a "renewables-plus-nuclear hybrid strategy" is not without its own friction. For such a strategy to succeed, policymakers must simultaneously address three structural nuclear challenges: (1) accelerating permanent waste disposal sites, (2) rebuilding public trust through transparency and participation, and (3) reforming regulatory and construction governance to avoid chronic delays and cost overruns (O. N. E. Agency, 2025; Solutions, 2025; WSP, 2025). Without progress on these fronts, nuclear energy (like an over-reliance on variable renewables without storage) remains an incomplete climate solution. A truly pragmatic energy transition requires honesty about *all* technologies' limitations, not selective criticism.

4. Suggestions for improving other things

The previous section sets the stage for this one, which offers useful advice on improving renewable energy rules worldwide. If you have a clear, well-thought-out plan, you might be able to get people to care, build infrastructure, work with other countries, and raise money. As a result, this will speed up the switch to cleaner energy, make it fairer, and make it last longer. We provide clear steps to follow and examples of policy landscapes from around the world in 2025 so you can put our advice into action. The International Energy Agency (IEA) and REN21 have both written about how these processes should be slow, include everyone, and have clear, verifiable goals to help people get what they want (Association, 2024).

4.1. Increased Financial Support

One of the biggest problems with getting many people to adopt renewable energy is that it costs a lot to set up. This is especially true in places where people don't have much money or are still developing. We need more money to make it through this. To encourage people to use renewable energy, governments and international groups need to offer both direct and indirect financial rewards.

The government can help by giving you tax breaks. Tax breaks and subsidies already give people money in many places, but they should be more frequent and available to more people. Countries could, for example, make investment tax credits or production incentives last longer. This would make both investors and consumers more interested in investing in renewable energy for the long term (Energy, 2024a).

How to Make It Happen: (1) Do audits every year to end fossil fuel subsidies and move the money to renewable energy sources, like China did in its 2025 Energy Law updates; (2) Set a rolling 5-year target for subsidy allocation, with 20% annual increases tied to deployment milestones; (3) Work with multilateral banks like the World Bank to get blended finance in low-income areas, with the goal of getting an extra USD 772 billion in investment by 2030, according to REN21 estimates (Association, 2024).

Green financing and low-interest loans:
People who want to switch to renewable energy might find it easier to do so if they can access low-interest loans or green bonds. To get more money, there should be more public-private partnerships (PPPs), and green financing methods could be better (Agency, 2023a). (1) Start national green bond programs with tax breaks, based on the EU's REPowerEU Plan (which aims for 45% of energy to come from renewables by 2030); (2) Set up PPP task forces to co-finance 50% of projects, starting with pilot programs in rural areas; (3) Use digital platforms to keep an eye on things and report ROI every six months.

Ways to Lower Risk: To attract private investors to renewable energy projects, governments and international groups should offer insurance or guarantees to reduce risk. This is especially important in new markets, where investors might be scared off by risks they think they see (Agency, 2023a).

How to do it: 1. Give national development banks risk guarantees, like India's plan to have solar panels on rooftops by 2025. 2. Set up insurance pools for weather-related risks that pay for 80% of the costs up front. 3. After a year, have outside groups look at the results and make changes if the default rate is below 5%.

4.2. Public Awareness and Education Campaigns

Renewable energy needs more than just money and technology to work. It also needs to be accepted by the people. People in local communities often don't support renewable energy projects because they don't know enough about the benefits of clean energy or have been given wrong information. Governments and organizations need to focus on public education and awareness campaigns to change people's minds and encourage greater acceptance of renewable energy technologies.

Getting people involved early in the planning process can help ease concerns about how the land will be used, how it will look, and what negative effects might occur. You can do this by having public meetings, talking to people in the area, and working with local environmental groups (I. R. E. Agency, 2024).

What you need to do: (1) Make all projects over 10 MW do community impact assessments, like Denmark's 2025 wind policy updates; (2) Set up local advisory boards with 50% resident representation; and (3) Use surveys to keep track of engagement, aiming for 70% approval rates before breaking ground.

Awareness Campaigns: Governments and NGOs should launch campaigns nationwide to educate people about the long-term benefits of renewable energy, such as creating jobs, improving air quality, and achieving energy independence. These campaigns should also discuss how renewable energy can improve people's health by reducing the harm from fossil-fuel-based power generation (Agency, 2021a). What to do: (1) Set aside 1% of energy budgets for multimedia campaigns, based on the U.S. IRA's public outreach; (2) Work with schools to include the program in their lessons, reaching 10 million students each year; (3) Use pre- and post-polls to see if attitudes have changed by 20%.

Encouraging Renewable Energy Education: Schools and training programs should be rewarded for offering specialized classes in green business, energy management, and renewable energy technologies. Not only would this help people learn more, but it would also help build a skilled workforce for the renewable energy industry (Laboratory, 2024). (1) Use national funds to pay for half of the training costs, like Germany's Energiewende apprenticeships; (2) Set up online platforms for 100,000 certifications each year; and (3) Track employment to see how many people get jobs in renewables within six months.

The successful transition to renewable energy is not only a matter of technological and financial solutions, but also one of public acceptance. Resistance to renewable energy projects, particularly in local communities, often stems from a lack of understanding or misinformation about the benefits of clean energy. Governments and organizations must focus on public education and awareness campaigns to change mindsets and foster greater acceptance of renewable energy technologies.

Community Engagement: Engaging communities early in the planning process can address concerns about land use, aesthetics, and potential negative impacts. This can be done through public consultations, local community meetings, and collaborations with local environmental organizations. Implementation Steps: (1) Mandate community impact assessments for all projects over 10 MW, as in Denmark's 2025 wind policy updates; (2) Form local advisory boards with 50% resident representation; (3) Track engagement via surveys, aiming for 70% approval rates before groundbreaking.

Awareness Campaigns: Governments and non-governmental organizations (NGOs) should launch nationwide campaigns to educate the public about the long-term benefits of renewable energy, such as job creation, cleaner air, and energy independence. These campaigns should also emphasize the potential of renewable energy to reduce the negative health impacts associated with fossil-fuel-based power generation. Implementation Steps: (1) Allocate 1% of energy budgets to multimedia campaigns, inspired by the U.S. IRA's public outreach; (2) Partner with schools for curriculum integration, reaching 10 million students annually; (3) Measure success through pre/post polls showing 20% attitude shifts.

Incentivizing Renewable Energy Education: Academic institutions and training programs should be encouraged to develop specialized courses in renewable energy technologies, energy management, and green entrepreneurship. This would not only increase public knowledge but also contribute to a skilled workforce capable of supporting the renewable energy industry. Implementation Steps: (1) Subsidize 50% of training costs via national funds, as in Germany's Energiewende apprenticeships; (2) Launch online platforms for 100,000 annual certifications; (3) Evaluate via employment tracking, targeting 80% job placement in renewables within six months.

4.3. International Cooperation

The climate crisis affects everyone, so we all need to work together to fix it. Countries should share their knowledge, best practices, and technical expertise to accelerate the transition to renewable energy worldwide. We need to work together to stop climate change and ensure that people worldwide use renewable energy technologies in a fair and effective way.

Sharing knowledge and moving tech: It should be easier for developed and developing countries to share advanced renewable energy technologies. Governments, research institutions, and businesses from different countries could work together to accelerate the development of low-carbon solutions and make it easier to build renewable energy infrastructure worldwide (Agency, 2021a). What to do: (1) Set up tech hubs in both countries, like the REALM model for biodiversity-safe siting from Canada-IEA; (2) Hold annual forums for exchanges between 50 countries; and (3) Use joint KPIs to keep track of progress, with the goal of 20% tech adoption in partners.

International agreements like the Paris Agreement need to be stronger to ensure that everyone reduces their emissions and uses more renewable energy. These agreements can help ensure that both rich and poor countries set high goals for renewable energy and take the steps needed to reach them (Change, 2022). What you need to do to make it happen: (1) Change the NDCs to say they will triple by 2026, as COP28 says; (2) Make sure compliance happens through peer reviews; (3) Give $100 billion a year to help with compliance.

Rich countries should provide poor countries with more financial support and technical assistance so they can adopt renewable energy. This could mean low-interest loans, grants, and programs to help these countries prepare for a future powered by clean energy (Agency, 2021a). What to do: (1) The GCF should give out $50 billion in grants every year; (2) UN programs should train 1 million technicians; and (3) every year, send progress reports with suggestions for changes.

4.4. In conclusion: A Full Approach

Countries need to do a lot of things to switch to renewable energy. For example, they need to give money, teach people, build infrastructure, and work with other countries. Countries can switch to renewable energy in a fair and long-lasting way if they address the social, economic, technical, and policy barriers that stand in the way. To make the global energy system cleaner and fairer, governments need to work together. They can do this by making long-term policies stable, giving people and businesses reasons to invest, and getting countries to work together.

5. Addressing Criticisms of Renewable Energy: Land-Use and Material Sustainability

Critics often point out two main problems with renewable energy: conflicts over land use and the long-term durability of the materials used in solar panels, wind turbines, and batteries. This part looks closely at these worries, using recent 2025 studies as a guide, and suggests ways to address them that will keep the transition environmentally friendly. But these problems reveal a harsh truth: getting renewables to make up 80–90% of the world's electricity by 2050 could require significant mineral extraction, which could cause serious social and environmental problems if not handled properly.

5.1. Problems with land use

Deploying renewable energy, especially solar and wind, requires a lot of land—up to 10 times more per unit of power than for fossil fuels. This raises concerns about habitat loss, competition with farming, and effects on biodiversity (House, 2023). In the U.S., for example, local opposition has stopped or delayed 53 projects since 2008. This is often because of how they look, how they affect wildlife (like gopher tortoises in Georgia solar sites), or how they change farmland (Future Rft, 2025). According to the IEA's REALM tool (I. E. Agency, 2024c), a rapid push for clean energy worldwide could affect 25–40% of the best solar and wind resources and biodiversity hotspots that aren't protected. In India and Brazil, solar parks and biofuel expansions have forced people to move and accelerated deforestation, making "green" projects harmful to ecosystems.

But these effects don't have to happen. Utility-scale solar accounts for only 0.1–0.3% of U.S. land, yet it produces 13% of the country's electricity. This is much less than biofuels, which take up 66% of the land and produce 5% of the electricity. As shown in

California's pilots, dual-use strategies like agrivoltaics (solar over crops) or siting on degraded lands can restore soil while also making electricity. Offshore wind and solar panels on roofs help to avoid more problems. (I. E. Agency, 2024c; Future, 2025).

Integrated Solutions: Policies must use tools like REALM to ensure biodiversity-safe siting, with a focus on disturbed lands such as abandoned mines. But without strict enforcement, land hunger could hurt the climate credentials of renewable energy sources.

5.2. Materials' Long-Term Viability

Batteries, solar panels, and wind turbines all require important minerals like lithium, cobalt, and rare-earth elements like neodymium. Mining these minerals is harmful to the environment (deforestation, water pollution) and raises ethical concerns (child labor in cobalt mines) (Company, 2025). To reach net-zero goals, demand for lithium could rise by 1,500%, cobalt by 5 times, nickel by 6.5 times, rare earths by 4.6 times, and copper by 3.1 times by 2050. This would require more than 3 billion tons of minerals (Association, 2024) (D. E. Agency, 2024a). In the DRC (74% of cobalt), 40,000 children as young as 6 work in dangerous conditions to mine, which causes conflict and makes up to 20% of a battery's lifecycle emissions (D. E. Agency, 2024a) (Administration, 2025). Bolivia's lithium brines are harming the water rights and salars of indigenous peoples, and neodymium/silver extraction is destroying habitats in China and Peru (Agency, 2023c) (Energy, 2024b). China accounts for 80% of processing, making supply chains unstable and creating geopolitical chokepoints (Association, 2024).

There has been some progress: in pilot projects, 95% of EU batteries were recycled, and sodium-ion alternatives reduced the need for cobalt. However, these are only lab-scale and only cover 5% of today's demand (Energy, 2024a). The "green" transition could become a mineral-intensive disaster that worsens inequality in the Global South if there aren't major changes.

Solutions that work together: like the EU's Battery Regulation, which requires 50% recycled content by 2030 and invests in circular supply chains (Figure 10). Research and development for green batteries (like electrodes made from biomass) could cut impacts by 40%, but to make them work on a large scale, trillions of dollars need to be spent on ethical mining reforms (Bioenergy, 2024). Policymakers need to deal with the fact that the promise of renewables depends on avoiding a new resource curse.

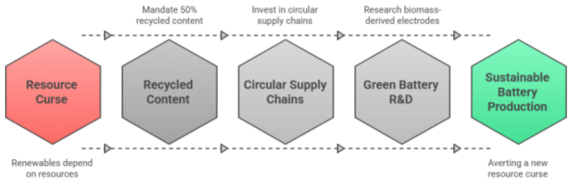

Figure 10. Sustainable battery production.

6. Conclusions

In conclusion, the world needs more sustainable, renewable energy sources, so we should switch to them. Renewable energy is important for both fighting climate change and protecting the environment. It also gives countries the chance to secure a steady supply of energy and rely less on imports. Switching to renewable energy can make countries less dependent on other countries for energy, make energy systems safer, and make the world a cleaner, stronger place (Agency, 2021a).

To make this change happen, though, policymakers need to be careful and make good decisions, and they need significant funding and ongoing research and development. The goal of a sustainable, low-carbon future will be hard to reach—and maybe even impossible—without these basic steps. Governments, businesses, and civil society must collaborate to surmount the financial, technical, and social obstacles to renewable energy adoption, including intermittency gaps that can be mitigated with nuclear complements such as SMRs. By 2050, the demand for minerals could quadruple. Cobalt mining in the DRC uses child labor, and lithium extraction in Bolivia dries up ecosystems. If this continues, "green" growth could become socially regressive.

World can make the future of energy cleaner and greener for everyone and the planet if they work together at all levels, from local projects to global cooperation. But only if policies deal with these trade-offs directly and include nuclear hybrids, ethical mineral chains, and fair land use. A comprehensive, long-term strategy necessitates pragmatism: renewable energy sources alone will be inadequate without fundamental systemic reforms, lest the transition exacerbate the inequalities it aims to address.

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No ethical approval was required for this study. The authors confirm that all ethical standards of scientific research were strictly followed, including the avoidance of data fabrication, falsification, plagiarism, and other forms of research misconduct.

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