

Sustainability of Decarbonization: A Systematic Review of Policy Integration and Regional Realities

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ABSTRACT

In the face of accelerating climate change, global efforts to decarbonize have intensified, but the sustainability of these policies remains contested. While emissions reductions have become central to climate strategies, insufficient integration of equity, governance, and economic resilience often undermines long-term effectiveness. This review synthesizes peer-reviewed literature from 2014 to 2025 drawn from Scopus, Web of Science, and Google Scholar to evaluate how current decarbonization policies align with broader sustainability goals. The review examines regional disparities, governance structures, financial frameworks, and technological readiness to understand both the progress and shortcomings of existing strategies. Findings reveal that many policies disproportionately emphasize environmental targets while neglecting social justice, institutional coordination, and financial risk management. Regional case studies highlight that one-size-fits-all approaches are ineffective; successful decarbonization requires policy mixes tailored to local socioeconomic and governance contexts. Furthermore, the influence of political economy especially fossil fuel vested interests frequently hinders inclusive transitions. Despite digital innovations and emerging multi-level governance practices, systemic gaps persist in monitoring frameworks, participatory decision-making, and financial safeguards for vulnerable groups and markets. The review concludes that sustainable decarbonization demands integrated, equity-focused, and context-specific policy frameworks. Strengthening institutional coherence, expanding sustainability metrics, and investing in interdisciplinary research are essential to achieve resilient, inclusive, and environmentally sound energy transitions aligned with global development goals.

Keywords: Energy, Emissions, Decarbonization, Climate Policy, Sustainable

1. INTRODUCTION

Climate change is one of the most pressing global challenges of the 21st century, with far-reaching consequences for environmental systems, public health, and socioeconomic stability. Driven by anthropogenic greenhouse gas emissions from fossil fuel use, industrial processes, and land-use changes, global temperatures have risen by approximately 1.0 °C above pre-industrial levels [1]. Without significant mitigation efforts, global warming is projected to reach 1.5 °C between 2030 and 2052, increasing the frequency and severity of extreme weather events such as floods, wildfires, and droughts [2].

In response to these threats, international frameworks like the Paris Agreement and the United Nations Sustainable Development Goals (SDGs) particularly SDG 13 on Climate Action have accelerated global efforts to reduce carbon emissions and transition to sustainable energy systems [3]. Decarbonization policies now target transformations across energy generation, industrial operations, and land management to achieve net-zero emissions by mid-century [4]. However, beyond reducing emissions, true sustainability demands a more comprehensive approach one that integrates environmental protection, social equity, and economic resilience [5].

A sustainable decarbonization pathway must ensure not only lower emissions but also ecosystem preservation, equitable social transitions, and inclusive economic development [6]. Yet, renewable energy expansion while critical can create unintended consequences such as land-use conflicts, biodiversity loss, and displacement of communities, particularly in resource-rich regions [4]. These complexities illustrate the need for careful governance to avoid reinforcing environmental degradation or social injustice during the energy transition [7].

Emerging literature reveals growing implementation challenges surrounding renewable energy, including technological intermittency, land-use tensions, and fragmented policy landscapes. For instance, [8] identified significant hurdles to equitable energy transitions despite the emission-reducing promise of renewable technologies. These barriers are especially acute in sub-Saharan Africa and Asia, where high capital costs, regulatory uncertainty, and limited public awareness constrain renewable energy adoption [9].

Governance challenges further complicate sustainability outcomes. Effective climate policy requires integration across both vertical (national to local) and horizontal (cross-sectoral) levels of governance. Yet, institutional fragmentation and policy inconsistency frequently obstruct such coordination, limiting the effectiveness of decarbonization efforts [7]. Comprehensive and inclusive policy frameworks are needed to address social, technical, and economic barriers to low-carbon transitions [3].

These challenges are particularly evident in developing economies. A striking case is Indonesia's nickel industry, where the push for transition-critical minerals has led to

environmental degradation and social displacement, contradicting the principles of a just transition [4]. Similarly, Nigeria's abundant solar potential remains underutilized due to affordability issues, policy inconsistency, and public skepticism [9].

While existing studies have addressed elements of decarbonization and sustainability, few have systematically synthesized how sustainability principles are being operationalized within decarbonization policy frameworks. Bridging this gap is essential to inform more coherent, just, and environmentally sound strategies.

2. METHODOLOGY

2.1 Materials

This review synthesizes peer-reviewed literature published between 2014 and 2025, retrieved from reputable academic databases including Scopus, Web of Science, and Google Scholar. A structured keyword search and predefined inclusion criteria guided the selection of articles relevant to the integration of sustainability principles into decarbonization policies across global and regional contexts.

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3. OVERVIEW OF DECARBONIZATION

3.1 Overview of Decarbonization Policies

Decarbonization policies play a central role in global climate strategies by reducing greenhouse gas (GHG) emissions and transitioning energy systems away from fossil fuels

toward low- or zero-carbon alternatives. These policies are complex and multifaceted, incorporating regulatory frameworks, fiscal incentives, market-based mechanisms, and long-term strategic planning that collectively shape the global energy landscape [10].

3.1.1 Historical Context and Global Drivers

Fossil fuels have long dominated the world's energy mix, comprising roughly 80% of global primary energy consumption despite well-known environmental consequences. The 2015 Paris Agreement and related frameworks significantly catalyzed the shift toward decarbonization, prompting nations to adopt strategies aimed at achieving net-zero emissions by mid-century. This global commitment has encouraged a proliferation of diverse policy instruments supporting renewable energy adoption, energy efficiency, and carbon pricing.

3.1.2 Types of Policy Instruments

Decarbonization policy tools can be broadly categorized into four groups:

- Regulatory Instruments

These include legally binding mandates such as renewable portfolio standards (RPS), energy efficiency codes, and vehicle emissions standards, which require compliance from producers and consumers. Regulatory tools offer direct enforcement but may pose challenges in regions with weak institutional frameworks.

- Market-Based Mechanisms

Market-based policies like carbon taxes and emissions trading schemes (ETS) assign financial value to carbon emissions, incentivizing reductions in cost-effective ways. For example, emissions trading allows companies to trade emission allowances, promoting innovation and channeling revenue into low-carbon initiatives [11].

- Fiscal Incentives

Fiscal tools such as tax credits, feed-in tariffs (FITs), subsidies, and grants aim to accelerate clean energy deployment. FITs, in particular, have driven rapid growth in solar and wind capacity but require adaptive design to maintain market efficiency and avoid over-subsidization.

- Strategic Planning Instruments

National targets and climate action plans offer long-term guidance and policy certainty. While these strategies help align stakeholder interests and investment flows, their effectiveness depends on institutional enforcement and integration across sectors.

3.2 Sectoral Implementation and National Gaps

Decarbonization efforts have increasingly shifted from isolated initiatives to sector-wide and national strategies that integrate environmental, economic, and social goals. Key sectors such as power generation, transportation, heating and cooling, and heavy industry are now primary targets of emissions reduction policies. Norway's decarbonization of its island energy systems, for instance, demonstrates successful sectoral integration through electric vehicle subsidies, high carbon taxes, and bans on fossil fuel cars, all aimed at achieving net-zero emissions by 2050 [12]. Similarly, urban mobility strategies that prioritize public transport and discourage private car use have yielded reductions in emissions alongside improvements in social equity and accessibility [12].

At the national level, countries articulate their climate action strategies through Nationally Determined Contributions (NDCs) under the UNFCCC framework. These voluntary commitments are meant to guide sustainable development pathways tailored to local contexts. However, many NDCs lack the sectoral detail or implementation mechanisms required to meet the targets set in the Paris Agreement. Studies show that governance quality, cross-sector policy coherence, and institutional capacity heavily influence NDC effectiveness [7].

Despite policy advancements, implementation remains uneven. Many countries face infrastructure limitations, high financing needs, weak coordination among agencies, and limited access to climate technologies [3]. In addition, governments often grapple with difficult trade-offs between environmental goals, economic competitiveness, and social inclusion especially in resource-constrained settings. Addressing these trade-offs requires adaptive policy frameworks that are sensitive to political economy realities, institutional readiness, and regional disparities [5].

The evolution of policy thinking reflects a move toward integrated and inclusive approaches that holistically address sustainability. The success of these efforts depends on how well policies are tailored to specific national conditions including economic structure, governance capacity, and energy resource availability. These contextual variables underscore the need for customized strategies that bridge ambition with feasibility.

A summary of key decarbonization instruments, their benefits, and challenges is provided in Table 1.

Table 1: Summary of Key Decarbonization Policy Instruments, Their Benefits, and Implementation Challenges

Instrument Type	Examples	Benefits	Challenges
Regulatory	Emission standards, RPS	Enforceable, direct impact	Requires strong institutions
Market-Based	Carbon tax, ETS	Cost-effective, innovation-driven	Needs robust market structures
Fiscal Incentives	Tax credits, subsidies, FITs	Encourages investment	Risk of over-subsidization
Strategic Instruments	NDCs, national action plans	Long-term vision, stakeholder coordination	Often non-binding, lacks legal enforcement

3.3 Integration of Sustainability in Decarbonization Policies

Integrating sustainability into decarbonization policies is a complex and multidimensional process that extends beyond reducing greenhouse gas emissions. It requires aligning environmental goals with social equity and economic development to ensure that climate action supports the broader agenda of sustainable development [13], [14]. Achieving this alignment depends on political dynamics, institutional capacity, public values, and governance structures that influence how policies are designed, implemented, and monitored.

3.3.1 Urban Sustainability and Equity

Urban areas generate over 70% of global carbon emissions and are home to large populations vulnerable to climate impacts, including informal and low-income communities [15]. To avoid deepening social inequalities, urban decarbonization must prioritize equitable access to clean energy, affordable housing, public transportation, and resilient infrastructure. Policies must be inclusive by design, ensuring that climate initiatives do not exclude or disproportionately burden marginalized groups.

Multi-dimensional indicators that capture environmental, social, and governance (ESG) aspects are essential for tracking the sustainability of urban decarbonization efforts.

3.3.2 Policy Coherence and Alignment

Policy coherence involves aligning climate policies with national development goals to prevent conflicting objectives and ensure synergy [13]. An analytical framework by [13], emphasizes the role of ideas, institutions, and interests the "three I's" in shaping policy coherence. These political drivers determine whether sustainability is viewed as a priority or sidelined in favor of short-term gains.

Integration, therefore, is not just a technical task; it is a political process embedded in institutional arrangements and power dynamics.

3.3.3 Institutional Coordination and Governance

Governance fragmentation remains a major barrier to sustainability integration. Ministries and agencies often work in silos, with limited coordination between those responsible for climate policy and those overseeing development, energy, or transport [16]. This disjointedness hampers implementation and wastes opportunities for synergy.

Strengthening institutional mechanisms such as cross-ministerial task forces, integrated planning bodies, and shared data platforms can promote cohesive action [17].

3.3.4 Political Economy and Power Structures

Vested interests, particularly from fossil fuel industries, resist policies that threaten their dominance. These actors often leverage lobbying, political connections, and economic clout to delay or water down sustainable reforms [13]. However, involving civil society, indigenous communities, and grassroots organizations in policymaking can help counterbalance these forces and foster more inclusive governance.

Equitable decarbonization requires reshaping who holds influence in energy and climate decision-making spaces.

3.3.5 Normative Values and Public Opinion

Public attitudes and societal values deeply influence which sustainability policies gain traction. Competing worldviews such as prioritizing growth over conservation affect how climate problems are framed and what solutions are politically acceptable. Deliberative governance and participatory policy design help reconcile these differences and legitimize the trade-offs involved in sustainability transitions [18].

3.3.6 Energy Access and Social Inclusion

In many developing regions, energy access and affordability remain critical concerns. Sustainable decarbonization must ensure that clean energy technologies reach underserved populations and do not exacerbate existing inequalities [16]. Policies should integrate energy poverty alleviation with climate objectives, emphasizing both emissions reduction and inclusive development.

3.3.7 Monitoring, Evaluation, and Accountability

Transparent monitoring systems are essential for tracking sustainability outcomes. Composite indicator sets that measure emissions, social inclusion, governance quality, and economic

resilience provide a more complete picture of progress [15]. These tools support evidence-based adjustments, cross-country comparisons, and public accountability.

Despite growing awareness and conceptual progress, major implementation barriers remain. These include weak institutional capacities, political fragmentation, limited funding, and entrenched industrial interests [19]. Moving forward requires systemic governance reforms, stronger stakeholder engagement, and adaptive policy frameworks tailored to specific contexts.

3.4 Challenges and Gaps

Despite the growing policy momentum for decarbonization, a range of persistent challenges continues to hinder the effective implementation of sustainability-oriented decarbonization strategies. These barriers cut across social, institutional, economic, technical, and governance dimensions, complicating efforts to achieve low-carbon transitions that are equitable, inclusive, and context-appropriate.

3.4.1 Social and Institutional Barriers

Decarbonization is not purely a technological shift it is a social transition deeply embedded in power structures and institutional relationships. [20] emphasize that the dominance of fossil fuel interests distorts political agendas and weakens policy implementation through lobbying, disinformation, and resistance to reform. This resistance often undermines climate ambitions and delays the deployment of clean energy systems.

Moreover, decarbonization policies risk deepening inequality if justice and equity are not embedded in their design. Workers in fossil-dependent sectors and marginalized communities are particularly vulnerable. Without a just transition framework, the shift to low-carbon systems may reproduce or worsen socio-economic disparities [21].

3.4.2 Policy Design and Implementation Barriers

Many decarbonization policies particularly in the Global South suffer from top-down design approaches that exclude key stakeholders and lack adaptive capacity. In Pakistan, for instance, [22] found that poor intergovernmental coordination and limited political will hindered climate adaptation efforts. The absence of participatory frameworks during policy formulation undermines trust, hampers ownership, and leads to ineffective implementation.

These issues parallel challenges faced in regulatory and fiscal instruments discussed earlier, where rigid enforcement or opaque incentive structures fail to align with local capacities or priorities.

3.4.3 Technical and Economic Constraints

Decarbonization policies must navigate complex energy system dynamics. [23] warn that technical policies such as curtailment caps designed to stabilize the grid can have unintended consequences, including increased emissions and fossil fuel reliance. Such paradoxes point to the need for integrated, systems-level planning rather than isolated interventions.

[24] extend this concern into the financial sector, highlighting that while low-carbon industries (“sunrise sectors”) are emerging, the decline of fossil-based sectors (“sunset sectors”) poses serious risks to financial stability through stranded assets and market volatility. These macroeconomic risks remain under-addressed in policy design, exposing a critical governance gap in fiscal and market-based mechanisms.

3.4.4 Governance and Political Challenges

Sustainability transformations are inherently political and contested. [25] argue that fragmented governance structures, institutional inertia, and competing political interests obstruct systemic change. These conditions limit the ability of governments to coordinate across ministries, manage stakeholder conflict, and implement adaptive policy cycles. Although institutional coordination has been flagged as essential in earlier sections, governance reform remains insufficient to meet the scale and urgency of decarbonization.

3.4.5 Equity and Justice Deficits

Traditional economic instruments such as carbon taxes and emissions trading schemes often overlook issues of distribution and justice. [21] contend that these tools, while efficient, can impose higher burdens on vulnerable populations unless equity safeguards are built in. The Green New Deal model offers an alternative by integrating justice and social inclusion into the core of climate action, yet operationalizing such comprehensive frameworks remains limited in both scope and scale.

3.4.6 Knowledge and Evaluation Gaps

There is a notable scarcity of interdisciplinary, context-specific research that addresses the full range of decarbonization challenges. Most existing frameworks emphasize emissions metrics while neglecting economic and social dimensions. [15], [22] stress the need for multidimensional evaluation tools that account for local realities, institutional performance, and equity outcomes. However, these tools are still underdeveloped and inconsistently applied across countries. This is summarized in table 2.

Table 2: Summary of Key Challenges in Integrating Sustainability into Decarbonization

Category	Description	Implications
Social & Institutional	Vested interests, exclusion of stakeholders, social inequality risks	Undermines legitimacy and inclusiveness of transition
Policy Design	Top-down models, poor coordination, lack of adaptive planning	Weakens implementation and trust
Technical & Economic	Grid integration limits, stranded asset risks, insufficient financial tools	Increases emissions and reduces investor confidence
Governance & Political	Fragmented systems, resistance to reform, limited capacity for conflict management	Slows down systemic change
Equity & Justice	Market-based tools lacking redistribution mechanisms	Disproportionate burdens on vulnerable groups
Knowledge & Evaluation	Narrow metrics, lack of integrated frameworks, limited context-specific research	Impairs accountability, learning, and course correction

3.5 Regional Case Studies of Decarbonization Policy Integration

The global push for decarbonization reveals that uniform policy approaches are insufficient for achieving sustainability. Regions differ vastly in their resource endowments, governance systems, institutional capacities, and social structures. To understand how decarbonization policies can be tailored for sustainability, this section presents regional case studies selected based on their geographic diversity, climate vulnerability, and the availability of peer-reviewed evidence. Together, these examples illustrate how local context influences the design, implementation, and effectiveness of decarbonization pathways.

3.5.1 United States: Grid Planning and Regional Disparities

Farnsworth and [26] investigate the regional disparities in the U.S. energy system using an Ideal Grid capacity expansion model. Their findings highlight that states like Texas, with high energy demand and fossil infrastructure, face very different decarbonization trajectories than states like New Hampshire, which rely more on nuclear energy. This variability reveals that centralized decarbonization frameworks risk imposing uneven burdens or producing suboptimal outcomes.

Rather than applying uniform policy prescriptions, the study emphasizes the necessity for decentralized and flexible policy frameworks that reflect regional energy profiles. It

reinforces earlier arguments on the importance of policy coherence and the need for institutional structures that allow for differentiated regulatory and market-based approaches tailored to local needs.

3.5.2 Europe: Comparative Climate Policy Outputs

In a comparative study of Austria, Germany, and the United Kingdom, [27] develop a framework to assess the “density” and “intensity” of national climate policy outputs. Their analysis shows that while all three countries actively pursue decarbonization, the quality, ambition, and implementation of their policy instruments vary significantly due to differing political priorities, institutional arrangements, and financial capacities.

This case illustrates that having a wide array of policies is not sufficient what matters is how these instruments are designed, resourced, and enforced. The study reflects the broader challenge of aligning national policy mixes with sustainability objectives, and it echoes the earlier discussion on the limitations of fragmented governance and uneven institutional capabilities.

3.5.3 Africa: Digitalization and Policy Gaps in Nigeria and South Africa

[28] explores how emerging digital technologies such as blockchain, smart grids, and mobile platforms are beginning to reshape energy systems in Nigeria and South Africa. These technologies hold the promise of decentralized, low-carbon energy access. However, their potential remains largely unrealized due to outdated regulatory frameworks and insufficient institutional support.

The gap between technological innovation and policy readiness reflects deeper governance challenges. The study highlights how weak institutional alignment, poor infrastructure, and lack of strategic planning constrain the transition to sustainable energy systems. It adds to the growing body of literature calling for governance frameworks that can respond proactively to technological shifts while ensuring social equity and energy access.

3.5.4 Central Asia: Governance Constraints and Fossil Dependency

[29] examine energy transitions in Central Asia, focusing on Kazakhstan, Kyrgyzstan, Tajikistan, Turkmenistan, and Uzbekistan. These fossil-rich nations continue to rely heavily on hydrocarbons, and their centralized governance structures limit transparency, flexibility, and stakeholder participation. Weak regulatory institutions and limited data availability further complicate efforts to diversify energy systems.

The Central Asian experience underscores how institutional rigidity and political inertia act as structural barriers to sustainable decarbonization. It demonstrates that even where renewable energy potential exists, the lack of coherent policy instruments and effective

monitoring systems can stall progress supporting earlier claims about the importance of adaptive governance and coordinated planning.

3.5.5 South Asia: Fragmented Adaptation and Limited Governance Reflexivity

[30] analyze climate adaptation strategies in Bangladesh, India, Nepal, and Pakistan. Their study finds that while short-term disaster management responses are increasingly common, longer-term, flexible adaptation strategies are lacking. Institutional reflexivity exists in pockets but is undermined by fragmented multi-level governance and limited transboundary collaboration.

This case reinforces the argument that sustainability integration requires more than technical solutions; it demands anticipatory and collaborative governance models. The South Asian context shows how weak coordination across national and local institutions can limit the effectiveness of climate policies and hinder the mainstreaming of sustainability into development planning.

3.5.6 Cities and Multi-level Governance: Local Leadership with Structural Limits

[31] explore the evolving role of cities in global climate governance, noting that urban governments often set ambitious emissions reduction targets in the absence of strong national policies. Cities like New York, Berlin, and Lagos have pioneered local climate strategies, but these efforts often lack the legal authority, financial resources, and vertical coordination needed for long-term impact.

While transnational networks like C40 have enhanced knowledge sharing and policy innovation, the study cautions that city-level action must be embedded within supportive national and international frameworks. The findings confirm that sustainable decarbonization requires not only local innovation but also institutional scaling mechanisms to sustain and replicate successful initiatives across governance levels.

3.5.7 Urban Africa: Institutional Weakness and Climate Vulnerability

[32] provide a comprehensive look at adaptation strategies in Douala, Lagos, Dar-es-Salaam, Accra, Addis Ababa, and Mombasa. These African cities face acute climate risks, compounded by rapid urbanization, under-resourced institutions, and planning deficits. Although local adaptation initiatives are emerging ranging from flood management to community engagement they are often poorly integrated into formal urban planning frameworks. Table 3 Shows the Comparative Summary of Decarbonization Challenges and Opportunities by Region

Table 3: Comparative Summary of Decarbonization Challenges and Opportunities by Region

Region/Cluster	Key Challenges	Opportunities
United States	Regional disparities in energy infrastructure and demand	Flexible federal system enabling regional customization
Europe	Variations in policy ambition and implementation	Strong evaluation frameworks and policy benchmarking
Nigeria & S. Africa	Misalignment between tech innovation and policy	Potential for decentralized digital energy systems
Central Asia	Centralized governance; fossil lock-in	High renewable potential; need for reform-oriented policy
South Asia	Short-termism; fragmented adaptation	Institutional learning and emerging reflexivity
Global Cities	Legal and financial limitations; lack of vertical integration	Strong innovation capacity and civic leadership
Urban Africa	Governance gaps; weak integration of adaptation strategies	Local engagement and international support opportunities

4. RESULTS AND DISCUSSION

4.1 Equity and Justice

A critical theme emerging from this review is that sustainable decarbonization cannot be pursued in isolation from questions of equity and social justice. In many regions particularly, urban areas and developing economies climate vulnerability is compounded by deep-seated social and economic inequalities. Without explicit attention to these disparities, decarbonization efforts risk reinforcing historical injustices and creating new forms of exclusion. Policies that prioritize emission reduction alone, without addressing the distributional consequences of transition pathways, may erode public support, deepen resistance, and ultimately undermine long-term sustainability goals.

The integration of equity as a core principle of decarbonization is not merely aspirational but fundamentally practical. As transitions away from fossil fuels reshape entire sectors and livelihoods, marginalized communities and workers are at heightened risk of displacement and economic insecurity. A just transition framework provides a mechanism for balancing environmental imperatives with social protections, ensuring that the burdens and benefits of climate action are shared fairly. This review illustrates that embedding equity into policy design enhances not only legitimacy but also implementation success, particularly when supported by participatory governance structures that give voice to those most affected by change.

4.2 Governance Reform

The role of governance in shaping decarbonization outcomes is both profound and multidimensional. Across the literature, there is consistent evidence that institutional fragmentation, competing mandates, and entrenched power dynamics act as significant barriers to effective policy integration. In many contexts, particularly where fossil fuel interests wield substantial influence, political and institutional inertia slows the pace of transition and distorts policy priorities. Governance failures often manifest not in the absence of policies, but in the disjointed and incoherent manner in which they are implemented.

Reforming governance structures to support sustainable decarbonization requires coordinated efforts across all levels national, regional, and local as well as across sectors such as energy, transport, housing, and finance. Cities have emerged as powerful actors in this space, often pioneering innovative responses to climate challenges. However, the effectiveness of city-led initiatives is contingent upon supportive national frameworks that enable vertical coordination, resource flows, and regulatory clarity. The need for governance reform, therefore, extends beyond administrative restructuring to include the cultivation of political will, institutional capacity, and inclusive decision-making mechanisms that can adapt to complex and evolving transition contexts.

4.3 Financial Stability

The transition to a low-carbon economy is not only a technical and political challenge but also a major financial undertaking. Shifting investment from fossil fuel-based systems to renewable and resilient infrastructure demands both large-scale capital mobilization and mechanisms for managing economic disruption. The rise of low-carbon sectors and the concurrent decline of fossil-based industries introduce new forms of financial risk, including stranded assets, market volatility, and structural imbalances in economies heavily reliant on extractive industries.

This review reveals that current financial governance frameworks are not adequately equipped to anticipate or absorb these risks. Policy incoherence, weak climate-finance alignment, and limited investor guidance have contributed to uncertainty that may delay or misdirect capital flows. Ensuring financial stability during the transition will require integrated strategies that blend public investment with incentives for private sector participation, while also embedding climate risk into financial regulation and disclosure. Ultimately, a resilient financial system must be one that not only supports decarbonization but is also itself transformed to function in a carbon-constrained world.

4.4 Regionalization and Context

One of the clearest insights from the regional case studies is that decarbonization is deeply contextual. Local political cultures, governance capacities, resource availability, and social dynamics significantly shape how climate policies are formulated and implemented. The

diversity observed across regions from the decentralized energy planning required in the United States to the governance challenges facing Central Asian states demonstrates that success depends on how well policies respond to these distinct conditions.

Tailored policy mixes that align regulatory mandates with economic incentives and innovation support mechanisms are more likely to be effective than uniform strategies applied indiscriminately. In developing regions, for example, the promise of digital technologies to accelerate energy access and efficiency is contingent on overcoming regulatory lag and infrastructural gaps. Similarly, cities' ability to drive change is often limited by institutional constraints and misaligned national priorities. These examples reinforce the principle that effective decarbonization must be grounded in localized knowledge, designed for adaptability, and responsive to the evolving realities on the ground.

4.5 Research Needs

Finally, this review identifies a pronounced gap in the interdisciplinary knowledge base necessary to support sustainable decarbonization. Much of the existing scholarship remains siloed, with limited integration between technical, social, economic, and governance dimensions. While there is growing recognition of the need for comprehensive approaches, empirical research that evaluates the real-world performance of integrated policy frameworks remains limited particularly in low- and middle-income countries where data scarcity and institutional fragility complicate analysis.

Monitoring and evaluation systems also remain narrowly focused on emissions metrics, overlooking the broader sustainability indicators that would allow for a more nuanced understanding of policy impacts. Expanding these systems to incorporate equity, governance quality, economic resilience, and institutional adaptability is essential for effective feedback and continuous improvement. Further research is also needed to examine the socio-economic implications of emerging technologies in the energy sector, especially as digitalization becomes more central to energy governance in developing contexts. Advancing this body of knowledge will be critical to designing transitions that are not only technically viable but also socially legitimate and politically feasible.

5. CONCLUSION

This review has shown that while global decarbonization efforts have gained momentum, their sustainability depends on more than just reducing emissions. Effective decarbonization policies must be deeply rooted in social equity and economic resilience, reflecting the realities of diverse regions and communities. A recurring theme across the literature and case studies is that narrowly focused, technocratic approaches often generate unintended consequences deepening inequality, straining local governance systems, and undermining long-term development objectives.

The findings underscore that governance reform is foundational to advancing sustainable transitions. Without coherent institutions, inclusive stakeholder engagement, and coordinated action across governance levels, policy efforts remain fragmented and vulnerable to political resistance. Equally important is the need for policies that explicitly prioritize justice, ensuring that vulnerable populations and fossil fuel-dependent workers are supported through fair and inclusive transition pathways. Cities and local actors can play a leading role in this process, but only if they are empowered within broader multi-level governance structures.

Going forward, national and regional governments must design integrated policy frameworks that balance climate ambition with social protection and economic feasibility. This includes strengthening financial governance to mitigate transition-related risks and fostering regulatory environments that support technological innovation, particularly digital solutions that expand energy access in underserved regions. Above all, continuous investment in interdisciplinary research and robust monitoring systems will be essential to assess impact, adapt policy, and ensure that sustainability remains central. These actions, taken together, will help align decarbonization strategies with global climate goals while promoting justice and resilience at every level of implementation.

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