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The Role of Public Policy Innovation in Accelerating Climate Change Mitigation

Wilda Sumarsyah
Universitas Negeri Surabaya, Indonesia
wildasumarsyah@unesa.ac.id

Abstract

This research aims to analyze the role of public policy innovation in accelerating climate change mitigation efforts through adaptive and participatory policy approaches. Using systematic literature review methods and comparative policy analysis, the research examines various innovative practices implemented at the national and local levels, such as market-based instruments, green regulations, and multi-actor collaboration. The results of the analysis show that public policy innovations that integrate low-carbon technologies, economic incentive mechanisms, and collaborative governance are able to strengthen the effectiveness of mitigation strategies, reduce greenhouse gas emissions, and increase environmental resilience. These findings confirm that the success of accelerating climate change mitigation is greatly influenced by the government's capacity to create policies that are flexible, data-driven, and oriented towards long-term sustainability. The study makes a theoretical contribution by broadening the understanding of the relationship between policy innovation and climate action, while providing practical recommendations for policymakers to adopt innovative approaches that are responsive to social, economic, and ecological dynamics.

Keywords: *Public Policy Innovation, Climate Change Mitigation, Adaptive Policy, Collaborative Governance*

1. Introduction

Climate change has become an increasingly alarming global phenomenon with clear scientific indications of an increase in the earth's average temperature(Asnur et al., 2024; Winiasri et al., 2023). The Intergovernmental Panel on Climate Change (IPCC, 2023) report shows that global surface temperatures have increased by about 1.1 °C compared to the pre-industrial era, and are projected to continue to rise if greenhouse gas emissions are not immediately suppressed (Kaack et al., 2022). This increase triggers disruptions to the climate system, including changes in rainfall patterns, extreme heat waves, as well as seasonal shifts that affect agricultural productivity and water availability. Global warming is also accelerating the melting of glaciers and ice sheets at the North and South Poles, thereby altering the Earth's energy balance and increasing the risk of more severe climate in the future (Dale, 2016**;** Suprayitno et al., 2024)**.**

The direct impact of global warming is clearly visible on sea level rise and the intensity of natural disasters. National *Oceanic and Atmospheric Administration* (NOAA, 2022) data shows global sea level rise has averaged about 3.3 mm per year over the past three decades, threatening coastal areas with erosion, saltwater intrusion, and loss of important habitat(Kern & Rogge, 2016). In addition, the frequency and severity of extreme weather events such as tropical storms, flash floods, and wildfires have increased significantly due to warmer and humider atmospheres(Dale et al., 2020; Surana et al., 2023). This phenomenon not only causes economic losses and fatalities, but also suppresses ecological systems and magnifies social injustices, especially for vulnerable communities in developing countries. These findings underscore the urgency of mitigating climate change through innovative and globally coordinated public policies (Haines et al., 2007; Moleka, 2023).

Climate change mitigation efforts face serious challenges because conventional policies are often unable to significantly reduce greenhouse gas emissions (Dechezleprêtre et al., 2011). Traditional policies that rely on a top-down approach—such as emission quality standards or energy efficiency standards—tend to be reactive, fragmented, and less adaptive to economic dynamics and technological developments (Meckling & Allan, 2020). These regulatory instruments also often ignore incentive mechanisms that encourage private sector innovation, thereby hindering the diffusion of low-carbon technologies on a wide scale. In addition, funding constraints and institutional capacity gaps in many countries, particularly in developing regions, mean that conventional policies

do not have sufficient leverage to achieve ambitious targets as set out in the Paris Agreement (Rosenbloom et al., 2020).

Conventional policies also often fail to internalize the external costs of greenhouse gas emissions into the economic system. Carbon tax schemes or emissions trading, which are supposed to provide clear price signals, are often implemented with low tariffs and narrow scope due to political pressures and concerns about short-term economic impacts (Stiglitz & Stern, 2017). Cross-sectoral policy asynchronicity—for example between energy, transportation, and industrial policies—adds complexity, causing carbon leakage and reducing the effectiveness of reducing emissions. As a result, although countries have ratified international climate agreements, global emissions continue to rise, underscoring the need for more innovative, integrative, and science-based policy approaches to accelerate climate change mitigation (Puertas et al., 2023; Shaw et al., 2014).

Public policy plays a central role as a key instrument in achieving international climate mitigation targets, including the commitments contained in the *Paris Agreement* to keep global temperature rise below 2°C compared to the pre-industrial era (Bernauer & Schaffer, 2012). The government has the strategic authority to design regulations, incentives, and legal frameworks that direct economic and social activities towards low-carbon development (IPCC, 2022). Through public policy, countries can set *Nationally Determined Contributions* (NDCs), emission standards, and a renewable energy transition roadmap that provide certainty for the private sector while directing investment in clean technologies. Instruments such as carbon taxes, emissions trading systems, and renewable energy subsidy programs show how public policies are a key driver of the transformation towards a sustainable green economy (Veugelers, 2012; Rane et al., 2024).

In addition to providing a regulatory framework, public policy serves as a catalyst for the multi-level and cross-sectoral collaboration necessary for climate change mitigation. National governments can facilitate coordination with local governments, the industrial sector, and civil society to ensure effective and integrated policy implementation (Meckling et al., 2020). In the context of the Paris Agreement, public policies also encourage transparency and accountability mechanisms through emissions reporting, monitoring of NDCs, and periodic evaluations that spur increased mitigation ambitions (Ockwell et al., 2010). Thus, public policy not only regulates, but also inspires and strengthens the global partnerships that are essential to reduce greenhouse gas emissions in a sustainable and timely manner.

Climate change is a multidimensional challenge that involves complex interactions between environmental, economic, and social systems, requiring more innovative policy approaches than conventional models. Global socio-economic dynamics—such as population growth, rapid urbanization, and dependence on fossil energy—create uncertainty and accelerate the pace of greenhouse gas emissions (IPCC, 2023). Innovative approaches, such as the application of digital technology for real-time monitoring of emissions, green financing models such as *green bonds*, and artificial intelligence-based carbon market mechanisms, can improve the effectiveness and efficiency of mitigation. These innovations enable public policy to respond to changing conditions in a more adaptive, data-driven, and solution-oriented manner(Suprayitno et al., 2024). In addition, policy innovation is needed to encourage the participation of various stakeholders and create synergies across sectors. The complexity of climate change demands not only government action, but also the active involvement of the private sector, local communities, and international organizations in designing and implementing solutions (Meckling & Allan, 2020). Innovative approaches such as collaborative governance, economic incentive-based policies, and the use of behavioral science to change energy consumption patterns have been proven to improve compliance and accelerate the transformation towards a low-carbon economy. Thus, innovation is not just a complement, but a strategic need to ensure that public policies are able to anticipate increasingly complex and dynamic climate challenges (Kern & Rogge, 2016).

A number of international studies confirm the importance of public policy innovation in accelerating climate change mitigation. A study conducted by Meckling et al. (2020) shows that a combination of market-based instruments—such as carbon taxes and emissions trading—with low-carbon technology regulations can significantly reduce emissions in developed countries. Other research by Howlett and Mukherjee (2018) highlights the role of innovative adaptive and experimental policies, such as policy labs and pilot projects, in improving government responsiveness to climate uncertainty. These findings reinforce the argument that innovative, science-based public policies can be a key driver for achieving the targets set out in the Paris Accords. At the regional and local levels, research conducted by Sovacool et al. (2021) found that the implementation of community-based renewable energy policies and green incentive mechanisms in Southeast Asia has succeeded in increasing investment in low-carbon infrastructure and accelerating the energy transition. Meanwhile, research by Nhamo et al. (2020) emphasizes that the integration of climate finance and ecosystem-based adaptation policies can strengthen mitigation capacity in vulnerable developing countries. Both studies highlight the importance of socio-

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economic context and institutional capacity in determining the success of policy innovation. The relevance of these findings suggests that research on the role of public policy innovation is crucial for designing effective, inclusive, and sustainable mitigation strategies at various levels of government. Based on this, this study aims to find out The Role of Public Policy Innovation in Accelerating Climate Change Mitigation.

2. Research Methods

This study uses a qualitative method with a literature study design and comparative policy analysis to explore the role of public policy innovation in accelerating climate change mitigation. This approach was chosen because it is able to uncover conceptual relationships and best practices from various policy contexts at the global and national levels. Primary data is obtained from official climate policy documents, reports from international institutions such as the IPCC, UNFCCC, and *Nationally Determined Contributions* (NDCs) from various countries. Meanwhile, secondary data includes reputable journal articles, academic books, and relevant recent research reports. Data analysis is carried out through the Systematic Literature Review (SLR) technique with the stages of identification, selection, and synthesis of findings, to ensure that only valid and current literature is used as the basis for interpretation. Furthermore, the study applied comparative policy analysis to assess the variation in policy innovation in several countries with different mitigation achievements. This analysis utilizes the policy innovation and adaptive governance framework to assess the dimensions of policy novelty, implementation effectiveness, and driving and inhibiting factors. The validity of the findings was strengthened through triangulation of sources by comparing the results of a review of academic literature, emission statistical data, and international policy reports. This method allows researchers to draw comprehensive conclusions about how public policy innovations can be adapted and replicated to accelerate the sustainable reduction of greenhouse gas emissions.

3. Results and Discussions

Effective Public Policy Innovation

The progressive carbon tax is one of the effective public policy innovations in reducing greenhouse gas emissions by providing clear price signals to economic actors. This mechanism imposes a tax rate based on the amount of carbon emissions produced, thus encouraging industry players to switch to low-carbon energy (Stiglitz & Stern, 2017). The progressive implementation of the tax allows for tariff adjustments as mitigation ambitions increase, while generating state revenue that can be used to fund renewable energy and climate adaptation programs. Studies in Sweden and Canada show that carbon taxes designed with transparency and revenue redistribution are able to lower emissions without stifling economic growth (Noll et al., 2024).

The cap-and-trade system provides a flexible market framework by setting maximum emission limits (caps) and allowing industry players to buy or sell emission permits. This model creates economic incentives to reduce emissions below the set limit, as companies that manage to reduce emissions can sell excess quotas as carbon credits. The experience of the European Union through the EU Emissions Trading System shows that this policy is effective in reducing emissions from the industrial and energy sectors, while encouraging environmentally friendly technological innovation. The main advantage of cap-and-trade lies in its ability to balance market flexibility with environmental certainty (Ockwell et al., 2010).Green financial instruments such as green bonds and low-carbon technology investment incentives are important drivers for large-scale financing mobilization. Green bonds allow governments and the private sector to raise funds at competitive capital costs for renewable energy, sustainable transportation, and energy efficiency projects (Flammer, 2021). Meanwhile, fiscal incentives in the form of tax reductions or subsidies for investors who invest in low-carbon technologies accelerate the adoption of innovations in the industrial and transportation sectors. The integration of these financial instruments in public policy increases the attractiveness of green investments and accelerates the transition to a clean energy-based economy.

The use of digital technology for real-time emissions monitoring and data-driven analysis is an important breakthrough in supporting mitigation policies(Oktarina et al., 2021). Smart sensors, atmospheric monitoring satellites, and big data platforms allow governments to monitor emission levels with high accuracy and improve policies adaptively (Gütschow et al., 2022). In addition, the use of artificial intelligence (AI) for climate forecasting improves the ability to predict extreme weather patterns, thus supporting more targeted mitigation planning. Smart renewable energy systems—such as smart grids—also enable the integration of distributed energy sources and efficient demand management, strengthening the transition to low-carbon energy systems (Dewanto et al., 2023; Wantu et al., 2024).

Collaborative governance emphasizes the involvement of various stakeholders in the policy formulation and implementation process. *Public-private partnerships* can accelerate the development of green infrastructure

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through joint financing and technology transfer. The participation of local communities, including civil society organizations and indigenous groups, ensures policies are more contextual and socially acceptable, reducing resistance while increasing the effectiveness of implementation (Ansell & Gash, 2018). This collaborative model has been proven to strengthen policy legitimacy, mobilize resources, and foster a sense of shared ownership in mitigation actions. Another innovation in collaborative governance is the establishment of *policy labs*, which are policy experiments that involve academics, the private sector, and the public to design and test new policies before they are widely adopted. This approach allows for a fast, evidence-based learning process, while reducing the risk of implementation failure (McGann et al., 2018). *Policy labs* provide space for creativity and flexibility in the face of climate change uncertainty, and provide a crucial sustainable evaluation mechanism for refining public policy. Thus, collaborative governance based on *policy labs* is an important element in an effective policy innovation ecosystem to accelerate climate change mitigation (Dale, 2016).

The Impact of Policy Innovation on Mitigation

implementation of innovative public policies has been proven to result in significant reductions in greenhouse gas emissions in various countries. For example, the implementation of a progressive carbon tax in Sweden since the early 1990s has succeeded in reducing carbon dioxide emissions by more than 25% while maintaining stable economic growth (Andersson, 2019). Similar policies, such as *cap-and-trade* in the European Union through *the EU Emissions Trading System (EU ETS),* have reduced emissions of the industrial and power generation sectors by 41% between 2005 and 2021 (European Environment Agency, 2022). This data shows that market-based policy innovation and adaptive regulation are not only able to achieve national targets, but also contribute to the global commitments in the Paris Agreement (Ockwell et al., 2010).

Market-based instruments such as carbon taxes and emissions trading mechanisms provide price signals that drive efficient emission reduction. When carbon costs are internalized into economic systems, industry players have a strong incentive to reduce fossil energy consumption and adopt low-carbon technologies. A study by Stiglitz and Stern (2017) emphasizes that an adequate carbon price—around USD 50–100 per ton of CO_2—can accelerate the energy transition while keeping the rate of global warming below 2°C. This success confirms that innovative policies that balance economic incentives and regulatory certainty are key to reducing emissions measurably (Dale et al., 2020).Policy innovation also triggers increased investment in renewable energy through fiscal incentives, *green bonds*, and green financing schemes. According to a report by the International Renewable Energy Agency (IRENA, 2023), countries that adopt low-carbon investment incentive policies record growth in renewable energy investment of more than 20% per year. Tax incentives, feed-in rates, and public funding support encourage private companies to develop solar, wind, and biomass technologies. This investment flow not only accelerates the diversification of energy sources, but also reduces dependence on fossil fuels, which are a major contributor to greenhouse gas emissions (Rosenbloom et al., 2020).

Increased investment in clean energy has positive implications for the creation of green jobs in the manufacturing, construction, and maintenance services sectors of renewable technology. ILO data (2022) estimates that the transition to a low-carbon economy could create around 24 million new jobs globally by 2030. Innovative policies that support green industries, such as workforce training programs and green reindustrialization incentives, provide economic opportunities while reducing unemployment. Thus, mitigation policy innovations not only have an impact on the environment, but also strengthen the socio-economic dimension through improving people's welfare. Policy innovations that combine adaptation and mitigation can strengthen climate resilience at the national and local levels. Ecosystem-based approaches, such as mangrove restoration and sustainable forest management, double as carbon sinks and natural protectors from climate disasters, including floods and tropical storms (IPCC, 2022). Policies that support green infrastructure—such as sustainable urban development and adaptive drainage systems—provide mitigation benefits through emission reductions while increasing people's adaptive capacity. This synergy reduces vulnerability to the impacts of climate change, especially in coastal areas and vulnerable areas (Puertas et al., 2023).

The Role of Science And Technology In Reducing Policy Uncertainty

Complex and dynamic climate change contexts. First, science contributes through the provision of reliable evidence-based data to formulate policy. Climate modeling, big data analysis, and remote sensing systems allow for more accurate projections of emission trends, temperature rise, and socio-economic impacts. When policymakers have access to transparent scientific information, uncertainty about long-term risks is reduced, making decisions more targeted and based on empirical reality (Shaw et al., 2014). Second, technology plays a role in facilitating real-time monitoring and evaluation of policies. For example, Internet of Things (IoT) sensors and digital monitoring platforms can track emission levels, energy consumption, and changes in air quality with

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high precision. The collected data is then integrated into an artificial intelligence (AI)-based management system to generate predictive reports. Thus, policymakers can quickly assess the effectiveness of policies, adjust regulatory instruments, and reduce the risk of errors due to data uncertainty or outdated assumptions. Third, advances in information and communication technology (ICT) also increase the transparency and accountability of policy processes. Blockchain-based platforms, for example, can be used to record carbon credit transactions and verify emission reduction commitments by various parties. This mechanism not only reduces the potential for data manipulation, but also increases public and international stakeholders' trust in the policies implemented. Clarity of information and data disclosure contribute directly to reducing the political and economic uncertainty that often hinders green investment (Rane et al., 2024).

Fourth, scientific innovation in the field of renewable energy and energy storage technology provides greater economic certainty. As solar, wind, or hydrogen energy technologies become increasingly efficient and affordable, policymakers can set more realistic long-term targets, reduce transition cost uncertainty, and encourage the private sector to invest. Clarity on the cost and potential of the technology helps reduce market speculation, which has been a major factor in policy uncertainty. Finally, the integration of social science with environmental science is also important for understanding the dynamics of societal behavior and the social implications of climate policy. Interdisciplinary research allows for a more in-depth analysis of public acceptance of new policies, energy consumption patterns, as well as cultural factors influencing successful implementation. With a more comprehensive understanding of the social dimension, the formulated policies can anticipate resistance, increase community participation, and significantly reduce uncertainty stemming from socio-economic variables (Surana et al., 2023).

4. Conclusion

The results of this study can be concluded that public policy innovation is the main driver of accelerating climate change mitigation. The findings show that the implementation of economic instruments such as progressive carbon taxes, cap-and-trade schemes, and green bonds significantly reduces greenhouse gas emissions while increasing clean energy investment. On the other hand, the use of cutting-edge technologies—including digital-based emissions monitoring, artificial intelligence for climate prediction, and intelligent renewable energy systems—has been shown to reduce policy uncertainty and strengthen decision-making processes. Cross-sectoral collaboration through government-private partnerships, local community participation, and policy labs also strengthens adaptive governance, enabling policies to evolve in line with socio-economic dynamics and environmental challenges. Overall, the study emphasizes the importance of integrating science, technology, and collaborative governance as a foundation for effective policy innovation. By prioritizing evidence-based approaches, data transparency, and inclusive policy design, governments can create a regulatory framework that not only reduces emissions, but also promotes green economic growth and long-term climate resilience. These results provide practical implications for policymakers at the national and international levels, especially in formulating strategies that align with the Paris Agreement commitments and net-zero emissions targets, while strengthening people's adaptation to evolving climate risks.

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