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Analysis of Laws to Mitigate GHGs Emission in Developed Countries

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Abstract

This study examines the evolution of greenhouse gas (GHG) mitigation laws in developed countries, focusing on legislative trends, policy frameworks, and their role in global climate governance. Using the Human Development Index (HDI) to classify developed nations, mitigation laws were systematically extracted from the Climate Change Laws of the World (CCLW) database. The study categorizes these laws into resource, actor, and governance systems within a socio-ecological framework, further subdivided into 19 key subsystems. Since 1976, 59 developed countries have enacted 367 mitigation laws, accounting for 62% of global mitigation legislation. While early laws were limited in scope, the enactment of international agreements such as the Kyoto Protocol (1997) and the Paris Agreement (2015) accelerated legislative efforts. The most substantial increase occurred after 2000, with Germany leading in legislative activity. Despite progress, challenges persist, including enforcement gaps, financial constraints, and conflicting economic priorities, which can hinder the effectiveness of these laws. A temporal and spatial analysis of mitigation laws indicates a shift from isolated policies to comprehensive strategies incorporating financial mechanisms, carbon pricing, and green economic initiatives. Europe leads in legislative efforts, followed by the Americas and Asia. The study also highlights the predominant focus on energy, transport, and building sectors, emphasizing the role of policy in driving low-carbon transitions. While these laws contribute to emission reduction, further research is needed to assess their real impact, policy coherence, and enforcement mechanisms. Strengthening implementation frameworks will be essential to achieving long-term climate goals.

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Introduction

Climate change legislation has become a crucial tool for addressing greenhouse gas (GHG) emissions. Developed countries have enacted a growing number of laws aimed at reducing emissions by transitioning to renewable energy, implementing carbon pricing mechanisms, and promoting low-carbon transportation (UNDP, 2020). These legislative frameworks support compliance with international commitments such as the Paris Agreement and establish structured approaches for emission reductions (Erbach, 2021). By 2020, 56 countries had implemented direct climate laws, collectively covering 53% of global emissions (Rumble & Gilder, 2022). Research on climate change legislation has explored its effectiveness in emission reduction. Iskandar and Fankhauser (2020) analyzed regulatory actions across 133 countries, concluding that climate laws contribute to a measurable decline in carbon dioxide emissions. Farzaneh and Banimostafaarab (2023a, 2023b, 2025) examined climate adaptation and disaster risk management laws, identifying an evolution toward broader policy objectives. Additional studies have assessed legislative trends in specific sectors, such as water, agriculture, and urban planning, reinforcing the predominance of mitigation laws in developed countries (Fakhri et al., 2023a, 2023b; Farzaneh et al., 2023; Banimostafaarab et al., 2023). However, gaps remain in understanding the structural axes and strategic priorities of mitigation laws, necessitating further research.

The urgency of mitigation stems from the need to curb GHG emissions and enhance carbon sequestration (Heshmati, 2021). The Intergovernmental Panel on Climate Change (IPCC) defines mitigation as a key strategy applicable across sectors, including energy, transportation, construction, industry, and land management (IPCC, 2023). Given their high energy consumption and historical emissions, developed nations play a critical role in these efforts, with countries like the United States, Germany, and Japan accounting for a significant share of cumulative emissions over the past 170 years (Papovich & Plumer, 2021).

While climate laws have driven emission reductions, their effectiveness varies based on governance structures, enforcement mechanisms, and political commitment. Many developed countries have integrated mitigation into broader national strategies, incorporating financial mechanisms and green initiatives (Farzaneh & Banimostafaarab, 2023a & 2023b). However, assessing the long-term impact of these laws requires a deeper examination of their legislative evolution and implementation.

This study fills existing research gaps by systematically analyzing mitigation laws in developed countries. Using the Climate Change Laws of the World (CCLW) database, it categorizes mitigation laws within a socio-ecological framework, focusing on three primary systems: resources, actors, and governance. The study further examines temporal and spatial trends, identifying key subsystems and their interconnections. By evaluating how these laws have evolved and their role in climate governance, this research provides insights into their effectiveness in achieving long-term emission reduction targets.

Materials and Methods

Review of development of countries

The United Nations Development Programme (UNDP) introduced the Human Development Index (HDI) in 1990 as part of the Human Development Report (Bagolin

& Comim, 2008). The HDI is a composite index that measures average achievements across three key dimensions of human development: a long and healthy life, education, and a decent standard of living (Conceição, 2022). The HDI value ranges from zero to one (UNDP, 2021). Developed countries typically exhibit high HDI values (0.8 or higher), classifying them within the "very high human development" category. These countries are characterized by stable governance, accessible education and healthcare systems, high life expectancy and quality of life, and robust economic growth (World Population Review, 2023). For this study, developed countries were identified based on their HDI values, as presented in Table 1.

The analysis focused on 59 developed countries, which were selected based on their HDI scores and included in the study due to their classification as "very high human development" nations. Countries that did not meet the HDI threshold for high development (below 0.8) were excluded from the analysis. This criterion ensures a consistent and comparable sample of nations with the capacity and infrastructure to implement and enforce climate change mitigation laws. It is important to note that while there is no direct relationship between a country's HDI value and the number of mitigation laws it has enacted, the inclusion of HDI serves solely to classify the countries as developed. There is no implied causality or correlation between HDI and legislative activity.

Table 1 presents the HDI values for each country along with the number of

Table 1. The HDI of developed countries and the number of mitigation laws related to climate change

Country	Human Development Index (HDI)	Number of mitigation laws	Country	Human Development Index (HDI)	Number of mitigation laws
Andorra	0.858	6	Luxembourg	0.930	6
Argentina	0.842	9	Malaysia	0.803	4
Australia	0.951	10	Malta	0.918	2
Austria	0.916	6	Mauritius	0.802	3
Bahamas	0.812	2	Montenegro	0.832	2
Barbados	0.810	2	Netherlands	0.941	6
Belarus	0.808	6	New Zealand	0.937	4
Belgium	0.937	8	Norway	0.961	9
Bulgaria	0.800	4	Oman	0.816	1
Canada	0.936	6	Palau	0.800	3
Costa Rica	0.809	5	Panama	0.805	7
Chile	0.855	7	Poland	0.876	12
Croatia	0.858	8	Portugal	0.866	2
Cyprus	0.896	1	Qatar	0.855	1
Czechia	0.889	6	Romania	0.821	10
Denmark	0.948	5	Russia	0.822	2
Finland	0.94	9	Serbia	0.802	3
France	0.903	9	Singapore	0.939	7
Georgia	0.802	3	Slovakia	0.848	10
Germany	0.942	20	Slovenia	0.918	2
Greece	0.887	15	South Korea	0.925	13
Hungary	0.846	4	Spain	0.905	9
Iceland	0.959	3	Sweden	0.947	4
Ireland	0.945	11	Switzerland	0.962	3
Israel	0.919	3	Turkey	0.838	5
Italy	0.895	14	UAE	0.911	2
Japan	0..925	13	UK	0.929	13
Kazakhstan	0.811	5	Uruguay	0.809	6
Kuwait	0.831	2	USA	0.921	9
Liechtenstein	0.935	5			

(UNDP,2021; Climate Change Laws of the World,2022)

mitigation laws enacted. While this table highlights the number of laws per country, the scope and limitations of this research must be considered due to the variations in legislative approaches and the context in which these laws are enacted.

Quantitative Analysis: Time-Series Analysis of Climate Legislation

This study employs time-series analysis to examine trends in climate change mitigation legislation over time. The analysis focuses on identifying patterns in legislative activity, observing how the number and distribution of enacted laws have evolved across different periods. This approach allows for a structured evaluation of legislative developments in response to climate policies and international agreements.

Qualitative Analysis: Ostrom Framework

To systematically analyze climate change mitigation legislation, this study applies the Ostrom framework, a widely recognized socio-ecological system (SES) framework that provides an integrated approach to governance and policy interactions (Palomo & Hernández-Flores, 2019). The Ostrom framework consists of several first-order components, including social and ecological factors, external influences, system interactions, and outcomes, which are further divided into second-order variables (Nagel & Partelow, 2022). It defines the interactions between four key subsystems: resource units, resource systems, governance systems, and users (actors) (Ostrom, 2009). These subsystems operate within social, economic, and political environments, shaping policy effectiveness and legislative outcomes.

Given the international scope of this study and the absence of clear geographical boundaries, the analysis focuses on three primary systems: resources, actors, and governance. Each system comprises several subsystems, identified through thematic content analysis of GHG emission reduction laws (Del Mar Delgado-Serrano & Ramos, 2015; Climate Change Laws of the World, 2022):

- Resource System: Includes six subsystems that regulate environmental conditions where resources are located or produced: land use, land use change and forestry (LULUCF), coastal zones, cross-cutting areas, environment, waste, and water.
- Actor System: Encompasses seven subsystems representing stakeholders that influence or are affected by resource systems: energy, buildings, transport, industry, agriculture, health, and tourism.
- Governance System: Addresses decision-making processes in climate mitigation policies and comprises six subsystems: economy-wide, public sector, finance, rural, urban, and social development.

All mitigation laws were assigned to these three systems using predefined categories derived from the SES framework (Del Mar Delgado-Serrano & Ramos, 2015). Each law was classified based on its primary legislative focus, ensuring consistency in categorization.

Laws were analyzed within the Ostrom framework using textual analysis to extract legislative themes and identify policy priorities. The analysis focused on evaluating how mitigation laws align with governance structures, actors, and resource management strategies. However, no inter-coder reliability assessment was conducted in this study.

Data sources and limitations

The primary dataset was obtained from the Climate Change Laws of the World (CCLW)

database, which provides an extensive collection of climate legislation. However, potential gaps in the CCLW database are acknowledged, as some laws may be missing due to differences in national reporting practices and data availability. To mitigate this limitation, supplementary data sources, such as national legislative repositories and government reports, were reviewed where possible. These gaps could influence the completeness of legislative trends observed in this study.

Results and discussion

Review of laws in mutual axes with mitigation

In developed countries, mitigation legislation extends beyond laws specifically targeting emissions reduction. Three additional axes are identified:

- mitigation and adaptation
- mitigation, adaptation, and disaster risk management
- mitigation and disaster risk management

Figure 1 illustrates the distribution of laws across these axes. The mitigation and adaptation axis exhibits the most extensive legal framework. Conversely, the number of laws pertaining to the other two axes is relatively small, likely due to their more recent emergence.

- Mitigation and Adaptation

The legislative framework for mitigation and adaptation in Belarus began in 1992 with the adoption of the Environmental Law. This area has seen significant legislative activity, with a total of 69 laws referencing the actor system. In terms of resource, actor, and governance systems, the sectors of LULUCF received the most attention, with 18 references. The transport sector followed with 25 references, while the economy-wide was mentioned in 24 laws. Among the countries studied, Georgia leads with the highest number of laws in this area, totaling five. The United Kingdom, New Zealand, France, and Denmark closely follow, each with four laws.

- Mitigation, adaptation and disaster risk management

Mitigation, adaptation, and disaster risk management axis has garnered attention in recent years, with its inaugural law being approved in 2019 as part of Turkey's 11th National Development Plan. Within this framework, the governance system is mentioned more frequently than other systems, with a total of 10 mentions. In terms of resources, actors, and governance, the economy-wide stands out with 4 mentions, followed by the water sector with 3 mentions, and economy-wide, which received 2 mentions. Notably, Turkey, Mauritius, the United States, Portugal, and Chile each have enacted one

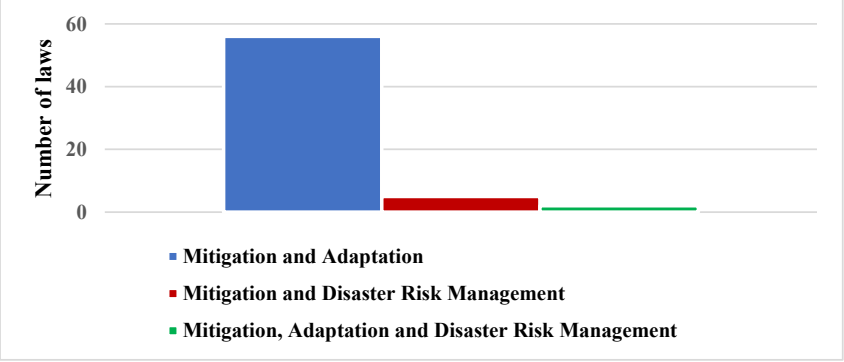

Fig 1. The number of laws in the mutual axes of climate change mitigation.

law pertaining to this axis.

- Mitigation, adaptation and disaster risk management

This area has recently become a major focus for new regulations. To date, only two legislative enactments have been observed within this axis: the U.S. Consolidated Appropriations Act of 2020 and the U.K. Subsidy Control Act of 2022.

Within this axis, the governance system exhibits a higher frequency of mention (three mentions) compared to the actor system (one mention). Notably, no legislative provisions were identified specifically addressing the resource system. The subsystems most frequently mentioned within this axis include the economy-wide (two mentions), energy, and finance (each with one mention).

Time and spatial review of climate change mitigation laws

As of 2022, the CCLW database recorded 928 enacted climate change-related laws worldwide. Developed countries accounted for a significant portion of this legislation, enacting 499 laws, representing 54% of the global total.

Focusing on subject matter, 593 laws (64% of all climate change legislation) specifically addressed mitigation. Of these, 367 originated from developed countries, constituting 62% of all mitigation laws globally. This further translates to 40% of all climate change-related laws enacted worldwide.

Figure 2 illustrates time review of mitigation laws enacted in developed countries. The first such law, the Norwegian Product Control Act No. 79, was enacted in 1976. However, legislative activity in this domain remained relatively slow, with only five additional laws enacted by 1988. From 1988 onwards, legislative activity accelerated, with at least one law enacted annually. By the year 2000, a total of 45 mitigation laws had been enacted, constituting 12% of all such laws. This indicates that the majority of mitigation laws in developed countries have been enacted since the year 2000.

A period of heightened legislative activity occurred between 2008 and 2015, with at least 18 laws enacted annually. This surge can be attributed to the commitments made by member states of the Kyoto Protocol to reduce GHG emissions.

Despite this progress, the urgency of addressing GHG emissions remains evident, as demonstrated by the enactment of five new laws in 2022 alone in countries such as France, Germany, Italy, and Spain.

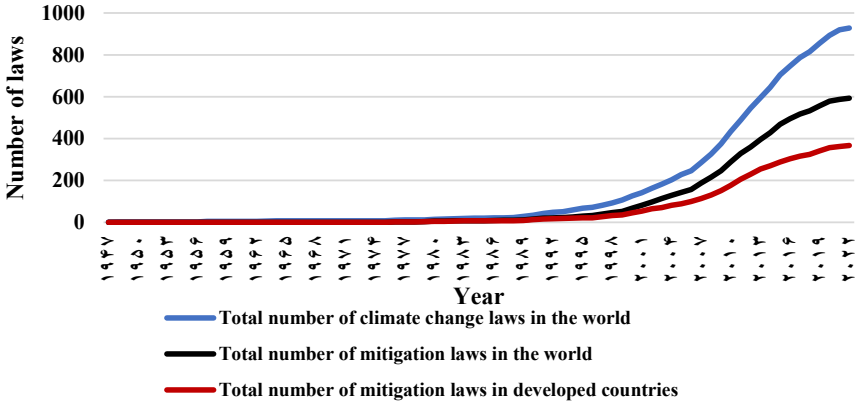

Fig 2. Time review of climate change mitigation laws.

A spatial review of climate change mitigation laws reveals a significant disparity across continents. Of the 59 developed countries included in this study, 37 are located in Europe, 9 in the Americas, 9 in Asia, 3 in Oceania, and 1 in Africa (Figure 3).

Europe demonstrates the highest concentration of mitigation legislation, with 246 enacted laws, constituting 67% of the global total. The Americas follow with 53 laws (14%), Asia with 48 laws (13%), Oceania with 17 laws (5%), and Africa with 3 laws (1%).

Within Europe, Germany, Greece, and Italy stand out as leaders in mitigation legislation, having enacted 20, 15, and 14 laws, respectively. In the Americas, the United States leads with 9 enacted laws. In Asia, both South Korea and Japan are leading in this domain, each with 13 enacted laws.

Time and spatial review of climate change mitigation laws in in Socio-Ecological Systems

This section analyzes how legal frameworks for GHG emission reduction address each component of the socio-ecological system. As Figure 4 demonstrates, the actor system receives the most attention, with a substantial 565 mentions. The resource system follows with 93 mentions, while the governance system has the fewest, with 48.

Mentions across all three systems emerged in 1976, starting with the German Energy Saving Act within the actor system and the Norwegian Product Control Act No. 79 in both the resource and governance systems.

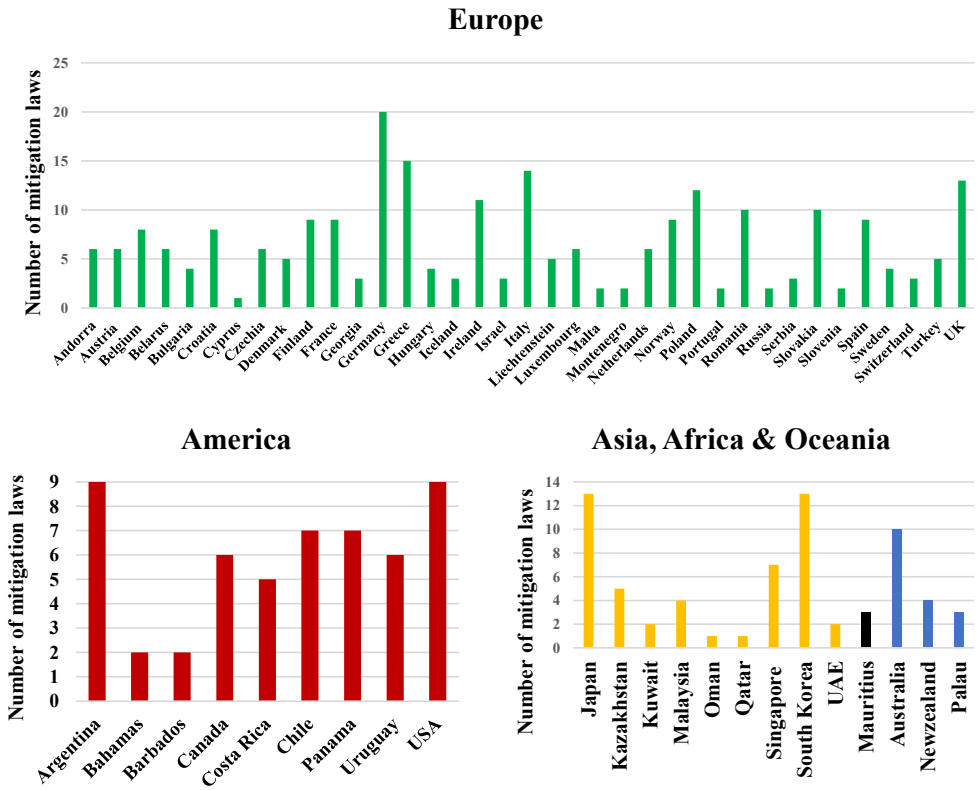

Fig 3. Spatial review of climate change mitigation laws.

Since 2000, the frequency of mentions across all systems has markedly increased. In the actor system, this upward trend peaked between 2007 and 2016, with at least 26 mentions annually. The resource system experienced its most significant increase between 2006 and 2012, with a minimum of six annual mentions. Since 2014, the governance system has also seen growing emphasis, with at least two annual legislative mentions. Figure 4 presents a time series visualizing the frequency of legal mentions to each system within mitigation legislation.

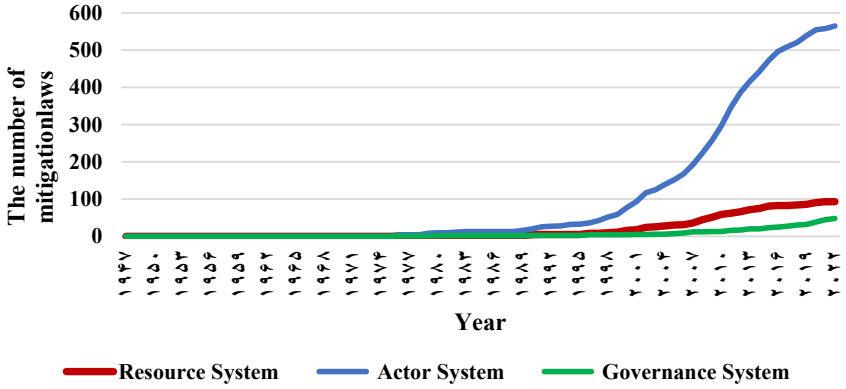

Fig 4. Time review of the climate change mitigation laws in socio-ecological systems.

The spatial review of socio-ecological systems by continent, as depicted in Figure 5, reveals that Europe exhibits a higher share of legislative mentions across all three systems: resources, actors, and governance. Specifically, Europe accounts for 62 mentions in the resource system, 328 in the actor system, and 28 in the governance system. Notably, the actor system consistently ranks highest across all continents, followed by the resource and governance systems, except in Africa. In Europe, 26 countries have enacted legislation related to the resource system, with Belarus and Italy leading with six mentions each. In the actor system, all countries have enacted relevant legislation, with Germany and Italy again demonstrating the highest activity, each with 30 mentions. However, in the governance system, only 16 countries have enacted legislation, with France leading with seven mentions. The majority of countries in this system have only one or two mentions, suggesting a relatively low emphasis on governance in mitigation legislation.

In the Americas, seven countries have legislation related to the resource system, with Canada leading with five mentions. In the actor system, all countries have at least two mentions, with the United States demonstrating the highest share with 22 mentions. The governance system is addressed by only five countries, with Canada again leading with three mentions. In Asia, six countries have legislation related to the resource system, with South Korea leading with three mentions. In the actor system, all countries except Oman have enacted relevant legislation, with Japan demonstrating the highest share with 26 mentions. In the governance system, only four countries have enacted legislation, with Japan again leading with nine references. It is important to note that while Oman has mitigation laws, it does not fall within the scope of

the socio-ecological systems framework in this analysis. In Oceania, Australia demonstrates the highest shares in the resource and actor systems, with three and 13 mentions, respectively. However, no legislation has been approved for the governance system in Oceania. In Africa, only the actor system is recognized, with no legislation established for the resource or governance systems.

Time and spatial review of climate change mitigation laws in in the Resource System

The resource system, based on the frequency of mitigation laws in developed countries, consistently encompasses the subsystems of "waste" (31 laws), "water" (26 laws), "LULUCF" (23 laws), "environment" (10 laws), and "cross-cutting areas" (3 laws). As depicted in Figure 6, the enactment of waste sector legislation commenced in 1976 with the Norwegian Product Control Act No. 79. Similarly, the water and LULUCF sectors were first addressed in the Singapore Building Control Act (1989) and the Costa Rican Energy Act (1990), respectively. Legislation within the environment sector began its trajectory in 1996 with the Costa Rica's Forest Act. Notably, a significant proportion of laws across all these subsystems have been enacted since 2007. While the number of laws remains relatively small, cross-cutting areas have emerged as a focal point for legislative attention in recent years. The inaugural law in this category, "Fuel Emission Trading," was enacted in Germany in 2019.

A spatial analysis of the resource system subsystems, as depicted in Figure 7, reveals varying legislative priorities across

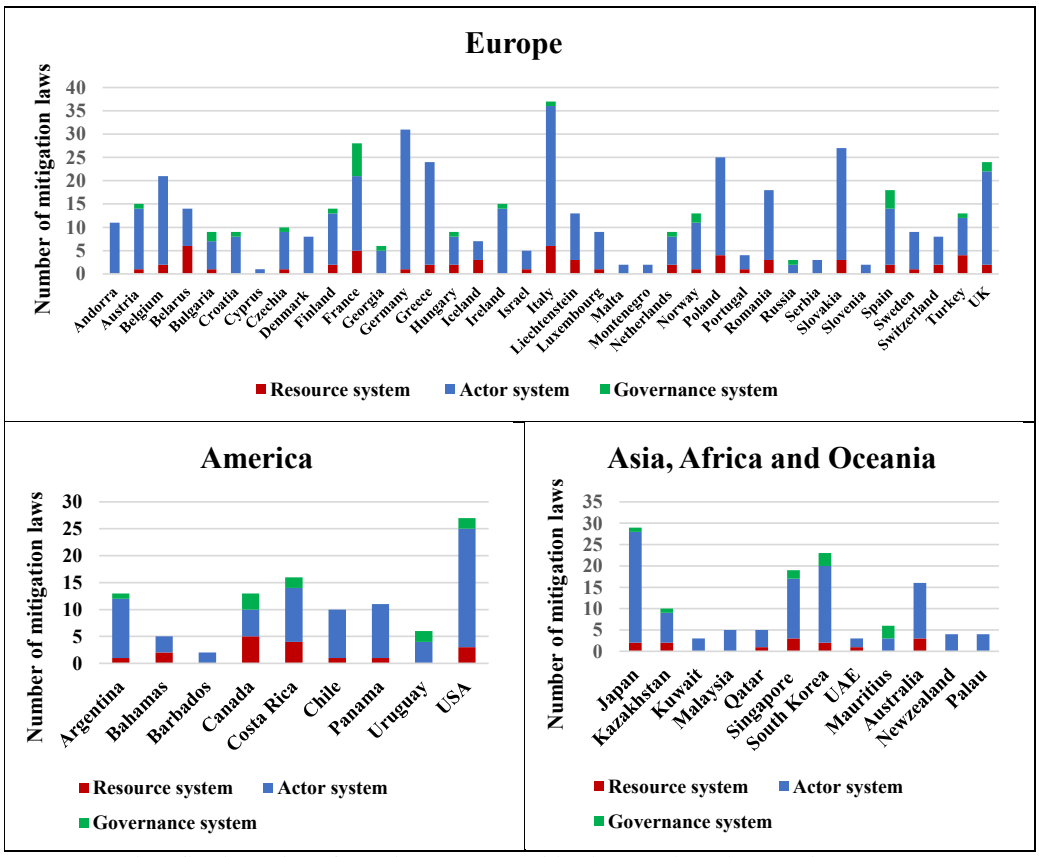

Fig 5. Spatial review of the climate change mitigation laws in socio-ecological systems

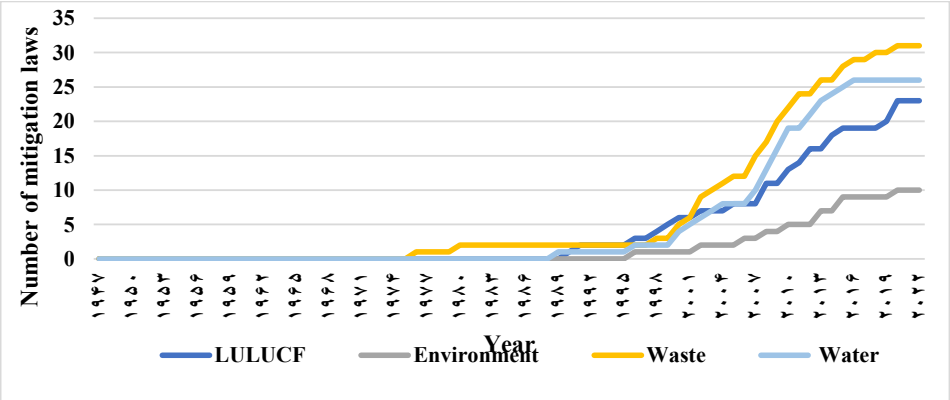

Fig 6. Time review of the climate change mitigation laws in the resource system

continents. In Europe, the waste sector garners the highest number of mentions (22), followed by LULUCF (16), water (15), the environment (7), and cross cutting areas (2). Belgium and Italy lead with three mentions each, while Liechtenstein, Slovakia, and Switzerland contribute two mentions each. Notably, within the environment and cross cutting areas sectors, each European country contributes a maximum of one mention.

In the Americas, LULUCF sector holds the top position with six mentions. The water and waste sectors follow closely, each with four mentions, while the environment sector has two mentions, and cross cutting areas have one. Costa Rica and Barbados each contribute two mentions, alongside the United States. Similar to Europe, within the environment and cross cutting areas sectors, each country in the Americas has a maximum of one mention.

In Asia, the highest number of mentions are allocated to the water (5 mentions), waste (4 mentions), and environment and LULUCF sectors (one mention each). No laws are defined for cross cutting areas. Singapore leads with two mentions, while Japan, Kazakhstan, and Qatar each contribute one. In Oceania, only two mentions are found in the water sector and one in the waste sector, all attributed to Australia. Notably, no laws are defined for resource systems in the African continent.

Time and spatial review of climate change mitigation laws in in the actor system

The actor system, categorized by the frequency of mitigation laws in developed countries, comprises several subsystems: “Energy (275),” “Transport (145),” “Building (78),” “Industry (44),” “Agriculture (14),” “Health (8),” and “Tourism (1).” As illustrated in Figure 8, a substantial majority of these sector-specific laws have been enacted since 2000, with over half approved since 2010.

Legislative activity within the energy and building sectors commenced in 1976 with the German Energy Saving Act. The health sector saw its first regulatory measures in the same year with the Norwegian Product Control Act. The transport and industry sectors followed in 1979 with the Japanese Rational Use of Energy Act. The agricultural sector’s legislative journey began in 1991 with the Carbon Tax Act and related regulations. Finally, the tourism sector saw its first regulatory measure in 1996 with the Costa Rica’s Forest Act.

Spatial analysis of the subsystems mentioned in the regulations of the actor system, as depicted in Figure 9, reveals a continental distribution. In Europe, the energy sector dominates with 182

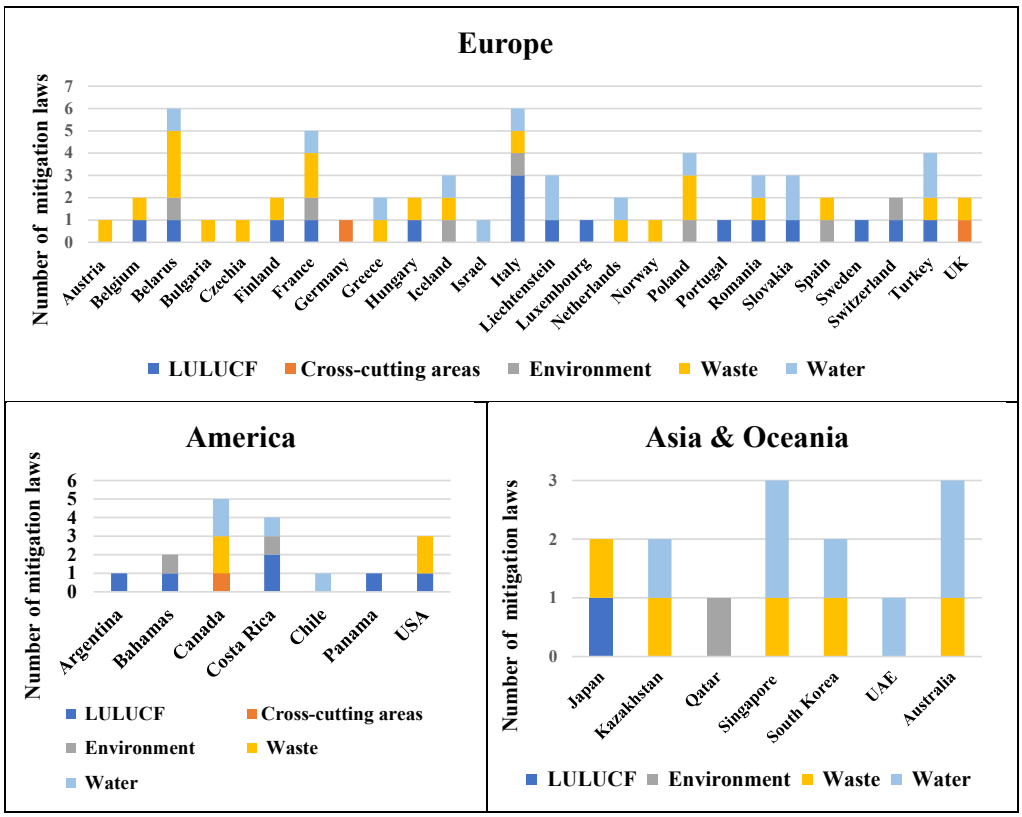

Fig 7. Spatial review of the climate change mitigation laws in the resource system

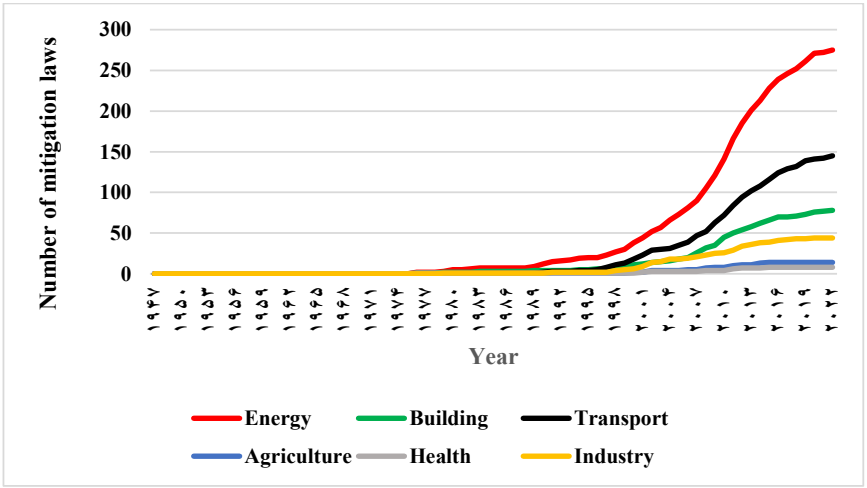

Fig 8. Time review of the climate change mitigation laws in the actor system.

mentions, followed by transport (108), building (55), industry (29), agriculture (9), and health (3).

Germany leads with 15 mentions across sectors, followed by Italy and the UK (8 each), Germany and Italy (6 each), Slovakia, Germany, and Belgium (3 each), and Poland (3). Within the health sector, each European country exhibits a maximum of one regulatory mention.

In America, all subsystems are mentioned, with energy holding the highest count (38), transport (17), building (11), industry (4), health (3), agriculture (2), and tourism (1) follow. The USA leads in energy (9), transport (6), and building (3), while the USA and Argentina share the lead in industry (2 each).

Asia demonstrates a strong focus on energy (39), transport (17), industry (11), building (9), agriculture (2), and health (1). Japan dominates in energy (12), transport (7), and building (4), while Singapore leads in industry (4). Other sectors in Asia exhibit a maximum of one mention per country.

In Oceania, energy (14), building (4), transport (2), agriculture, and health (each with 1) are the most mentioned subsystems. Australia leads across these sectors with 7, 3, 1, 1, and 1 mentions, respectively.

Finally, in Africa, only the energy (2) and transport (1) sectors are addressed, both in Mauritius.

Time and spatial review of climate change mitigation laws in in the governance system

The governance system for mitigation laws in developed countries, informed by the frequency ranking comprises several key subsystems. These include the "economy-wide" (32 mentions), "urban" (7 mentions), "public sector" (3 mentions), "finance" (3 mentions), "social development" (2 mentions), and "rural" (1 mention).

As illustrated in Figure 10, this governance system has undergone regulatory evolution since the Product Control Act No. 79 in Norway (1976), which targeted the urban sector. However, regulatory attention within this system has been

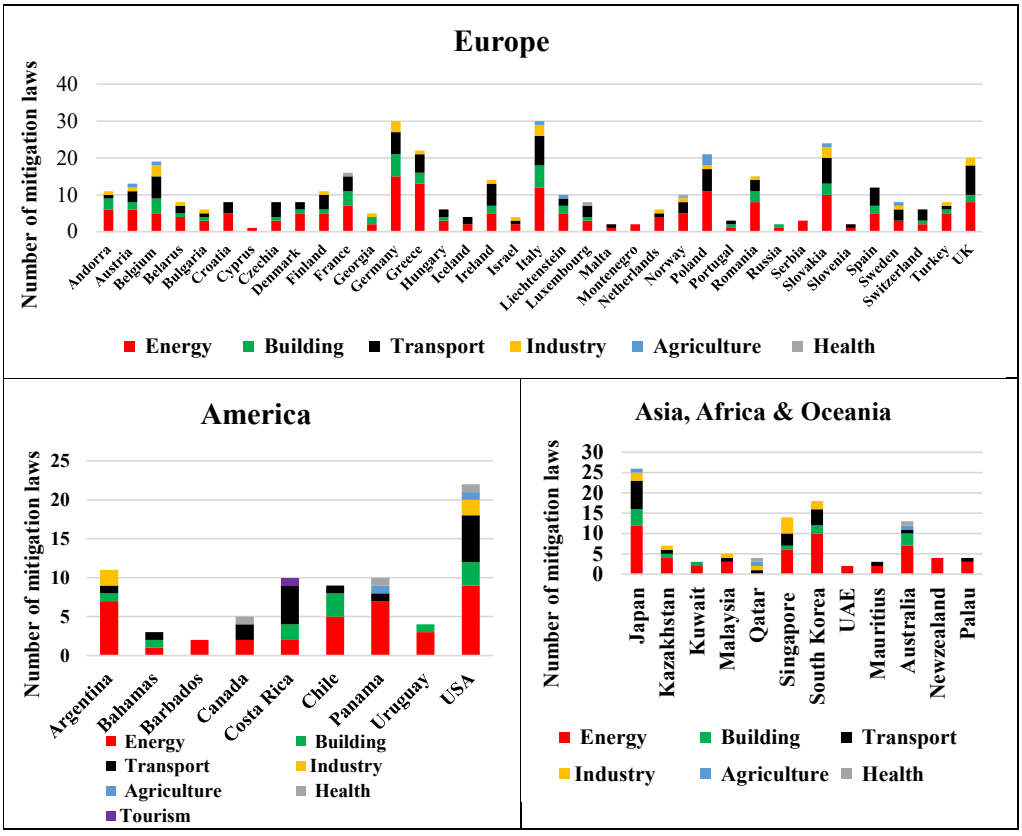

Fig 9. Spatial review of the climate change mitigation laws in the actor system.

relatively limited, with most subsystems experiencing significant regulatory activity only since 2006.

The "economy wide", initiated by South Korea's Energy Consumption Rationalization Act (1980), has seen a surge in regulations since 2015. The "social development" sector, exemplified by Law 26.093 (2006) Regimen of Regulation and Promotion of the Production and Sustainable Use of Biofuels (2006), has been a focus for regulatory action. The "rural sector" gained attention in 2011 with the Law on Act on the Creation and Facilitation of Use of Smart Grids. The "public sector" witnessed significant regulatory developments from 2017 onwards, including notable legislation in France and the UK (2020).

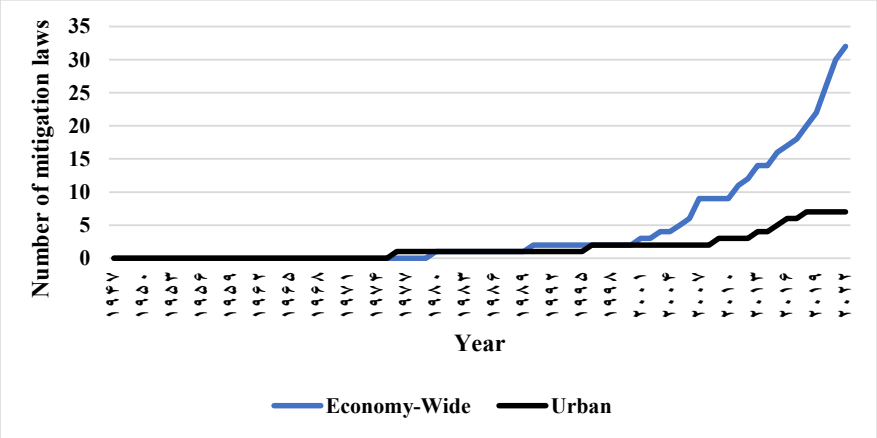

Fig 10. Time review of the climate change mitigation laws in the governance system.

Spatial analysis of the subsystems mentioned in governance system laws, as depicted in Figure 11, reveals that, with the exception of Oceania (which lacks such laws), the "economy wide" subsystem is most frequently mentioned across all continents. In Europe, the "economy wide" dominates with 19 mentions, followed by "urban" (4), "finance" (2), "public sector" (2), and "social development" (1). Spain (3), France (2), and the United Kingdom (2) are the primary sources of mentions across these sectors. Other sectors exhibit a maximum of one mention per country. In the Americas, "economy-wide" leads again with 7 mentions, followed by "urban" (2) and "social development" (1). Canada contributes 3 mentions, while Costa Rica contributes 2 to the "economy wide" and Argentina provides 1 mention each to "economy wide" and "urban." Asia demonstrates a focus on the "economy wide" (5 mentions), with additional mentions in the "rural" (1) and "urban" (1). Canada contributes 3 mentions, followed by Costa Rica with 2. Singapore is notable for having 2 mentions in the "economy wide". Finally, in Africa, Mauritius is the sole source of mentions, citing the "economy wide", "public sector", and "finance" once each.

Analysis of historical trends in mitigation laws within developed countries reveals a consistent upward trajectory in their adoption. Each decade has witnessed not only an increase in the number of such laws but also an expansion of their objectives and scope.

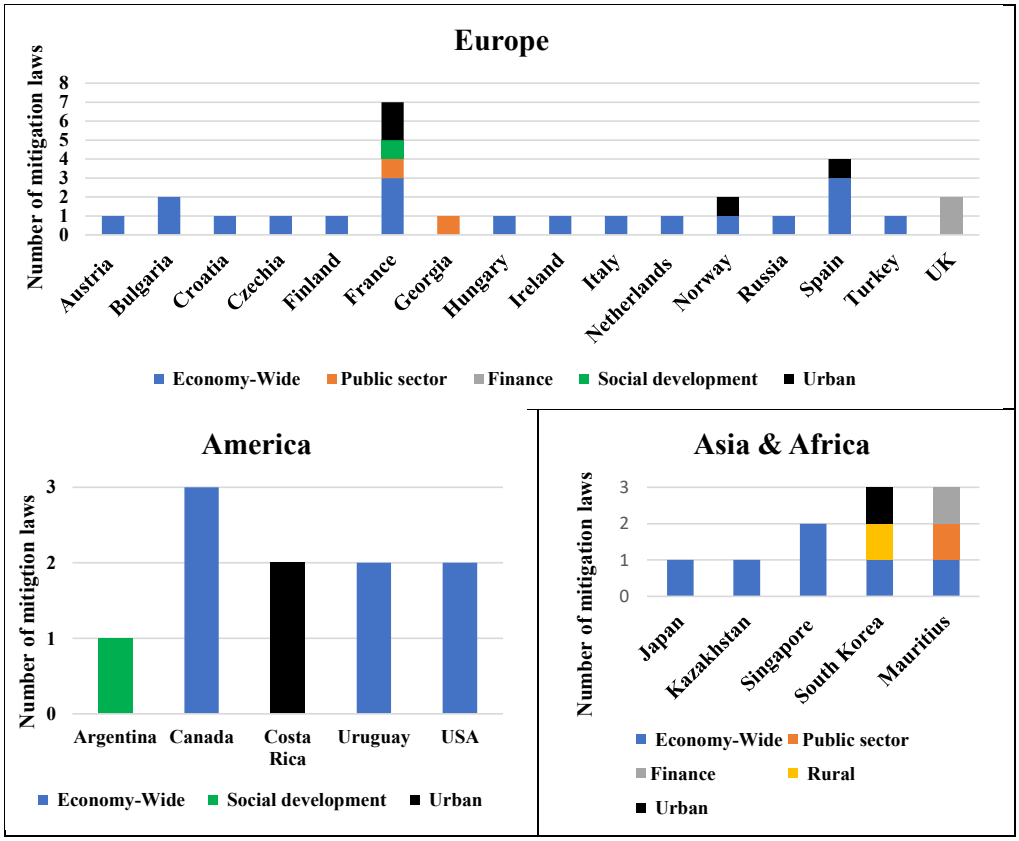

Fig 11. Spatial review of the climate change mitigation laws in the governance system.

The approval of mitigation laws commenced in the mid-1970s. During this era, characterized by limited awareness of climate change and its significance, efforts primarily focused on energy issues. Key examples include energy conservation initiatives in Germany, the promotion of energy-efficient products in Norway, and the advocacy for rational energy use, considered fundamental principles.

The 1980s witnessed a doubling of laws compared to the 1970s, with a notable surge in legislation within Asian countries. While energy-related concerns remained prominent, the objectives of these laws expanded to encompass national standards, regulations, policies, and programs. This period saw the establishment of energy efficiency standards in Japan, the formulation of a comprehensive GHG emission reduction policy in South Korea, the creation of the Atomic Energy Organization in Turkey, the implementation of Energy Conservation Performance Regulations in Kuwait, and the establishment of safety standards for buildings in Singapore.

The 1990s witnessed the enactment of 27 new laws aimed at mitigation, encompassing the establishment of policies, funds, and schemes. Key policy areas included the introduction of carbon taxes in Norway and Sweden, the creation of renewable energy and energy efficiency funds in Argentina and Belarus, the implementation of an environmental protection plan in Austria, the development of a comprehensive plan for integrated energy supply in South Korea, and the regulation of the electricity market in

the Netherlands, Belgium, and Belarus, alongside the establishment of a GHG emission management system in Belarus. The 2000s saw a significant increase in mitigation legislation, with approximately one-third of all such laws enacted during this decade, signifying a growing awareness of this critical issue. This period witnessed the formulation of various strategic plans and national strategies, alongside the negotiation of climate change agreements. Key policy focuses included the establishment of national agencies, the implementation of tax regimes, and the development of nuclear energy programs. Notably, several laws explicitly referenced "mitigation" in their titles, including the establishment of the mitigation fund in Italy, the implementation of Norwegian Global Emission Reduction Initiative, the creation of Canada Emission Reduction Incentives Agency, and the establishment of the Greenhouse Gas Emissions Management System in Poland.

The signing of the Copenhagen Accord in 2009 spurred a significant increase in mitigation legislation during the 2010s, with over half of all such laws enacted within this decade.

In addition to the policy areas emphasized in the 2000s, this period witnessed the emergence of various "green" measures, including carbon and GHG pricing, and disclosure legislation. Notable examples include energy disclosure laws in Australia, green finance regulations in Portugal, energy transition policies for green growth in France, the promotion of green economy measures in Italy, initiatives for a green economy transition in Kazakhstan, the establishment of the Green Fund in Greece, and the implementation of carbon pricing in Singapore and Canada.

From 2020 to 2022, an additional 26 laws aimed at mitigation were enacted. The emergence of the COVID-19 pandemic during this period shifted the focus towards financial and economic recovery, leading to the introduction of legislation such as the French Anti-Waste and Circular Economy and Purchasing Power Parity Act, budget laws in the UK, and financial regulations in the UK, Ireland, France, and Mauritius. Looking ahead, the commitments made by member states of the United Nations Framework Convention on Climate Change (2020), particularly those of developed countries with historical responsibilities for GHG emissions, will likely drive further legislative efforts to reduce emissions. These laws, once enacted, have the potential to significantly impact GHG emission levels. While some may be implemented immediately, others may be rolled out gradually, with varying timelines. The effectiveness of these laws is contingent upon the strength of implementing regulations within each country, with a strong rule of law generally correlating with greater impact. Overall, it can be concluded that global mitigation laws have, on average, demonstrated effectiveness in lowering emissions.

Beyond examining international legal frameworks addressing climate change and natural disasters, it is essential to consider the key factors that influence their practical effectiveness. Elements such as political commitment to implementing international obligations, public support for climate policies and civil society engagement, as well as economic barriers that may hinder investments in adaptation and mitigation measures, play a decisive role in shaping the efficacy of global legal regimes. A critical analysis of these variables can provide deeper insights into the challenges surrounding compliance and enforcement, while also offering pathways to enhance institutional and state-level adherence to

existing regulations.

Conclusion

This research provides a comprehensive analysis of climate change mitigation laws in developed countries, in the enactment of climate change mitigation laws since 1976. The analysis demonstrates a clear temporal evolution, with a surge in legislative activity following the Kyoto Protocol in 1997 and the Copenhagen Accord in 2009. Europe emerges as the leading region in terms of both the number of laws and the breadth of their scope. with countries such as Germany, the UK, and France enacting the highest number of mitigation laws and implementing extensive frameworks across various sectors, including energy, transport, and industry. The study identifies three key systems within the socio-ecological framework: resources, actors, and governance. The socio-ecological framework is an analytical tool that examines the interactions between social systems (e.g., actors and governance structures) and ecological systems (e.g., natural resources and environmental processes). In this context, the "actor" system, particularly the "energy," "transport," and "building" sectors, receives the most legislative attention, reflecting their significant contributions to GHG emissions. Notably, the "resource" system, specifically "waste" and "water" management, also demonstrates considerable legislative focus. Building on these findings, the analysis further reveals a shift from isolated legislative measures toward more comprehensive national programs, funding mechanisms, and sector-wide integration of climate policies. This evolution reflects a growing recognition that fragmented approaches are insufficient for meaningful GHG reductions. However, while legislative frameworks have expanded, the presence of laws alone does not guarantee their effectiveness. The strength of enforcement mechanisms, resource allocation, and political commitment significantly influence real-world outcomes. A key challenge remains the enforcement gap. Many countries with ambitious climate laws struggle with institutional capacity, financial constraints, and resistance from industries and political stakeholders. For instance, carbon pricing laws exist in multiple jurisdictions, yet weak compliance mechanisms and economic trade-offs often dilute their impact. Without stringent monitoring, reporting, and accountability structures, the intended benefits of mitigation policies may not fully materialize. To enhance the effectiveness of climate mitigation laws, policymakers should consider:

1. Strengthening Enforcement Mechanisms – Implement robust monitoring, reporting, and verification (MRV) systems, along with clear penalties for non-compliance.
2. Integrating Climate Policies Across Sectors – Align mitigation laws with energy, industrial, and economic policies to ensure consistency and avoid regulatory fragmentation.
3. Ensuring Political and Financial Commitment – Secure long-term funding and political stability to sustain implementation efforts. International cooperation can help bridge enforcement gaps, especially in regions with weaker institutional capacity.
4. Regular Policy Evaluation – Establish periodic assessments to measure legislative effectiveness, track emission trends, and incorporate technological advancements into legal frameworks. Future research should move beyond legislative counts and focus on evaluating policy impact using quantifiable indicators

such as emissions reduction rates, enforcement strength, and socio-economic feasibility. Additionally, examining the interaction between governance structures and legal outcomes will provide deeper insights into how laws translate into real-world climate action. Addressing these challenges will be crucial in ensuring that climate mitigation laws achieve measurable and lasting environmental benefits.

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