2024-05-07

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PII: S2199-8531(24)00088-X

DOI: https://doi.org/10.1016/j.joitmc.2024.100294

Reference: JOITMC100294

To appear in: *Journal of Open Innovation: Technology, Market, and Complexity*

Received date: 8 February 2024
Revised date: 28 April 2024
Accepted date: 2 May 2024

Please cite this article as: Phaninee Naruetharadhol, Aisling ConwayLenihan and Helen McGuirk, Assessing the Role of Public Policy in Fostering Global Eco-Innovation, *Journal of Open Innovation: Technology, Market, and Complexity,* (2024) doi:https://doi.org/10.1016/j.joitmc.2024.100294

Assessing the Role of Public Policy in Fostering Global Eco-Innovation

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ABSTRACT

The growing urgency of environmental problems, such as climate change, pollution, and waste management, has highlighted the importance of eco-innovation. It includes the development of sustainable solutions for goods and services. As corporations adopt sustainability practices, governments are increasingly essential in propelling eco-innovation.

Innovation and economic growth are inextricably linked since innovation helps reduce costs, increases productivity, and builds knowledge. Eco-innovation, requiring stakeholders' collaboration and knowledge sharing where public policy plays a critical role in fostering eco-innovation, is frequently catalyzed by climate change and environmental issues.

This paper provides an assessment of the public policy of several countries and its part in promoting eco-innovation. It explores how policy tools such as research and development investments, regulations, incentives, and infrastructure can be used successfully. It also explores

how such instruments influence small and medium enterprises due to their importance in environmental sustainability policy.

This research contributes to knowledge and adds to the literature by offering a global approach to the subject, complementing previous regional/single-country studies. It demonstrates the worldwide consequences of policy actions on eco-innovation and provides recommendations for policymakers, businesses, academics, and environmental stakeholders. The results highlight how governmental support is integral to ensuring the sustainability of a green future with economic benefits.

Keywords: Public policy; Eco-Innovation; Sustainability; SMEs

1. INTRODUCTION

The eco-innovation concept has gained increased traction over recent years. The idea offers solutions to environmental issues such as climate change, pollution, and waste disposal [1-3]. Eco-innovation is characterized by developing new or significantly improved services, processes, and products that support a sustainable environment. Such innovations also contribute to reaching the United Nations Sustainable Development Goals [4]. Like the traditional approach to increasing innovation, governments have a role in promoting eco-innovation. As businesses become more aware of the repercussions of their actions and are required to be socially and environmentally responsible, eco-innovation becomes increasingly important [5].

Innovation and economic growth are inextricably connected. Innovation stimulates economic growth by minimizing production costs, maximizing organizational output, and fostering the application of capital-intensive production methods [6-7]. The development of knowledge-based economies globally has prompted organizations to focus on innovative activities that create opportunities and sustainable economic activities [8]. According to Dogaru (2020),

societies and organizations that want to prosper in environmental sustainability must consider suitable innovative strategies.

Eco-innovation is an emerging business strategy that enhances a company's competitiveness and performance while promoting sustainability throughout a product's life cycle [9]. It can assist small and medium-sized enterprises (SMEs) expand their market reach, enhancing productivity, attracting new investments, improving profitability throughout the value chain, and maintaining a competitive edge. This is achieved by adhering to regulations and standards, particularly environmental ones.

Engaging in and implementing eco-innovation is a complicated process that requires holistic collaboration between stakeholders and access to knowledge and skills and differs from conventional innovative approaches [9]. Climate change and environmental issues present unprecedented challenges and opportunities for businesses to eco-innovate [10]. These challenges and opportunities have been, for the most part, caused by changes in public policy, regulatory requirements, government incentives, and public concern [11]. In this taxonomy, public policy can be defined as the deliberate contribution of government to reconcile environment and economic growth and provide guidance and framework for eco-innovation [12].

Governments have diverse approaches to coordinating the efforts and actions of all firms [13-14]. One of the most significant ways governments foster eco-innovation is through investing in research and development (R&D). Empirical studies indicate that governments invest in eco-innovation to create new pathways to sustainable development [14-15]. Chaparro et al. (2023) reveal that the European Commission (EC) tried to enhance consumers' and producers' adherence and understanding of the circular economy. Japan introduced the *Top Runner* program in 1998, geared towards bettering end-use products' energy efficacy [15]. Public policy concerning eco-

innovation encompasses a broad spectrum of measures, regulations, and initiatives by the government to control, support, and foster environmentally sustainable innovations [12]. Previous studies have explored public policy in innovative approaches and ascertained that the primary goal of public policy is to balance innovative practices and environmental concerns [16- 18] posit that while exploring the concept of public policy, such as funding R&D, regulatory policies, tax, and procurement policies, they are incorporated into the spectrum.

Until recently, studies on eco-innovation had not gained popularity in mainstream research linked to small and medium-sized enterprises (SMEs) [19- 20]. The same authors highlight that the effect of SMEs' innovative activities on the environment must be addressed. This paper aims to investigate the role of government policy in fostering eco-innovation, employed by various countries to encourage creative action and impact, particularly by SMEs.

Previous studies have explored the contribution of public policy in fostering eco-innovation in specific geographical regions. For example, Li et al. (2022) and Wu et al. (2023) focused on the contribution of government policy in fostering eco-innovation in China only. California's *Zero Emission Vehicle* (ZEV) mandate in 1990 was encouraged by government policies promoting the creation and commercialization of alternative fuel vehicles [20]. In a century characterized by mass information production and sharing, eco-innovation benefits from one country spread to other world areas [21]. Although environmental concerns are quantified in geographical locations, they are a global issue [22].

This research aims to assess the role of public policy in fostering eco-innovation on a global scale. The following questions guide the research:

1. What is the role of government policy in encouraging creative thought and action?

2. What are the current policy instruments employed by countries to foster their country's and, ultimately, global eco-innovation?
3. What is the significance of public policy in influencing eco-innovation within SMEs?

The research provides new evidence on the relationship between eco-innovation and positive development. This paper has a unique focus on analyzing the role of public policy in fostering global eco-innovation amidst pressing environmental challenges. This emphasis distinguishes the study from previous research efforts by comprehensively examining successful public policies that have demonstrably advanced eco-innovation in specific countries or regions. The paper expands the scholarly debate by digging into comprehensive case studies and addressing practical issues connected with policy implementation while also providing significant insights for policymakers, researchers, and practitioners. Furthermore, the proponents of this research acknowledge the changing landscape of SDGs and innovation. This provides evidence of the study's timely and valuable contribution to this dynamic subject. The findings can support and build on what previous research identified in the field of science. Identifying policy instruments that promote eco-innovation,

The paper is set out as follows: the next section 2 reviews the related literature, followed by Section 3, which presents details of the countries in the study and their associated policies. Section 4 explores the results, followed by the discussion and conclusion sections.

2. LITERATURE REVIEW

Investment in R&D is a significant driver of innovation [23]. Innovation is a strong driver of economic growth, particularly in developing new services, products, and processes [24]. Given

the growth and interest in environmental issues, such innovations have recently become more sustainable [25]. Empirical estimates from [26] indicate that eco-innovation increases the efficiency of carbon emissions, thereby reducing CO2E. Moreover, due to their resilience against fluctuations in oil and gas prices and geopolitical disruptions, renewable energy sources can provide nations with a more reliable energy supply than fossil fuels. Alternative energy sources can provide a more dependable and secure power source while reducing CO2 emissions [20]. As a result, policies must be implemented to reduce these harmful emissions by giving innovative environmental policies precedence [26]. Hence, it has prompted a recent move by governments and institutions such as universities and the European Commission to increase funding for R&D [27- 28]. Estimates show that gross domestic product (GDP) on R&D increased in 2017 globally [29] and continue to grow in 2023 [26]. According to the *Information Technology & Innovation Foundation* report [30], governments recognize that university-based research plays a key role in innovation and positive economic development. This report states that the United States government-funded university-based research using 0.20% of its GDP, less than Switzerland, which invested 3.7 times more. Other countries with high university research funding policies include Denmark, Sweden, Australia, Singapore, and more [30]. Governments and institutions have remained committed to promoting economic growth through research and development.

This study from [31] investigates the influence of green energy (REC), eco-innovation (ECO), and globalization (GLOB) on the ecological footprint (ECF) of the BRICS nations from 1990 to 2018. The panel nonlinear autoregressive distributed lag (PNARDL) method is utilized. The empirical findings suggest that the model exhibits co-integration. Positive shifts in renewable energy, eco-innovation, and globalization reduce the ecological footprint, whereas positive

(negative) shifts in non-renewable energy and economic growth increase the environmental footprint, according to the panel nonlinear autoregressive distributed lag PNARDL results [31].

R&D involves seeking knowledge to develop better procedures, technologies, products, services, and designs. For example, research in solar energy has led to new models of solar-powered cars that harness energy from the sun [32]. The cars contribute to less noise pollution and greenhouse gases than fuel-powered cars. Since the creation of the first solar cell in 1883, the development of solar-powered cars has come a long way and has heavily relied on research to where it is now [32].

2.1. The Role of Solar Energy in Addressing Sustainability Challenges

Sustainability, environmental concerns, and energy generation are all interconnected and essential to eco-innovation. The use of solar energy has primarily addressed the ecological concerns tied to energy generation. For a long time, the energy production sector was mainly in the gas and fossil fuel sectors. However, cleaner sources such as solar energy have revolutionized the current market. Solar energy answers the Sustainable Development Goals (SDGs) on energy access and environmental pollution by providing clean and affordable energy, energy for the future, positive development, and a foundation for championing gender parity [33]. The SDGs are ambitious and have received support from different governments, hence the move to solar energy.

The Earth is increasingly endangered by environmental impairments stemming from using conventional fuels. Nevertheless, solar energy is viewed as a leading solution to these problems [34]. Unlike fossil fuels, which are harmful to the environment through the gases they emit and contribute to climate change, solar energy harnesses the sun's power rather than clean electricity

produced exclusively without pollutants. The shift in paradigm about energy to renewable resources fits in with international efforts to deal with the issue of climate change and to achieve sustainable development goals. Among all the benefits of solar energy, one of the noteworthy ones is that it decreases reliance on fossil fuels, hence reducing air and water pollution, saving many ecosystems, and reducing the adverse impacts of climate change on poorer communities [35].

Furthermore, economic development and equity of society are the two elements promoted by applying solar energy. With the development of increasingly available and cost-efficient solar installations, local communities can produce their power, thus decreasing centralized energy grid dependence [36]. Therefore, it is clear that common SMEs become owners of mini energy plants, which ensure energy independence and help to maintain energy resilience in crisis areas where power outages or limited access to electricity is a problem. In addition, the widespread use of solar panels, in turn, produces jobs in the manufacturing, installation, and management sectors that result in surrounding economic growth and innovation within the renewable energy sector.

Moreover, the various social and economic conditions aside, renewable energy, particularly solar energy, directly promotes social equity and inclusivity [37]. Implementing renewable energy sources like solar power would ensure a clean and affordable electricity supply to communities that otherwise may not have adequate access to energy sources, including those residing in remote places and minorities. Such access to steady energy trades out socio-economic challenges based on people's habits to achieve education, healthcare, and economic prospects. In addition, solar projects can focus on social engagement and ownership to bring the residents close to the processes and involve them. It will ensure that residents can participate and take advantage of the initiatives.

Solar energy integration into the energy matrix strongly impacts sustainability and solving the green version of our generation problems. Solar technology enables us to access the sun's power, making it a clean, renewable energy source that can replace fossil fuels, which results in the reduction of greenhouse gas emissions and the fight against climate change [38]. Besides, solar power fosters the progress of the economy and the balance of society and provides energy access to ensure the achievement of sustainable development goals on an international stage.

2.2 Contribution of Government in Eco-Innovations and Market Failure

Public policy is vital in promoting eco-innovation globally, particularly by addressing market failures that hinder private investment in environmentally friendly technology. For example, market failures occur due to inadequate investment in eco-innovation, as the market fails to account for the total social and environmental costs associated with production and consumption [39]. Similarly, government intervention can rectify these flaws in the market and promote private investment in eco-innovation. In their study, Cecere et al. (2020) discovered that public funds can be viewed as supplementary to other forms of financing, particularly for smaller companies [40]. The government’s role in the success or failure of innovation contributes to eco-innovation in several ways [18]:

- Facilitating collaboration and sharing of ideas among different players, such as academia, government agencies, and industry. Governments help accelerate the development of innovations by supporting partnerships between partners who are looking to develop eco-innovations. Universities significantly impact the government's effort to implement sustainable development policies [41]. An instance of a government-university partnership is the cooperation employed between the Portland, Oregon, city government and the

Institute for Sustainable Solutions, Portland State University, to develop actor-centric transformative capacity [41].

- The government regulates the market to create a level field for the eco-innovators. The regulations set by the government on minimum environmental standards, such as waste reduction targets, energy efficiency standards, and emission limits, play a huge role in promoting eco-friendly innovations. The regulations create a market for environmentally sustainable innovations, directing the private sector towards environmentally friendly products and services [18].
- The government gives financial incentives to eco-innovator developers [42]. The government provides incentives in different forms, such as grants, tax breaks, and subsidies to encourage eco-innovation. The incentives help to offset the high costs associated with research and development and make eco-innovations a viable option for the private sector.
- The government invests in infrastructure for renewable energy, public transit, and recycling facilities, among other public goods that foster eco-innovation [42]. These expenditures have the potential to foster an atmosphere that encourages eco-innovation, laying the groundwork for further private investment in green technology. Overall, the government's role in eco-innovation is essential to overcome market failures and encourage private investment in environmentally friendly technology [15].

Governments may foster an environment that nurtures eco-innovation by offering financial incentives, regulating markets, encouraging cooperation and knowledge-sharing, and investing in public goods.

2.3 Eco-Innovation Policies

Government-sponsored innovation policy programs are designed to support, stimulate, and promote innovation-related activities [43]. Similarly, government policies give a framework for institutions and actors to work on implementing eco-innovations and unite critical actors and institutions to work on implementing the programs. The regulations put in place by the government are intended to address the environmental issues of the day, including pollution, resource depletion, and climate change. Public policy is critical in supporting global eco-innovation because it can offer the encouragement and support that firms and people need to embrace more sustainable practices and technology [43].

Encouraging R&D in environmental technology is one of the primary eco-innovation initiatives and incentives for corporations to invest in R&D and funds for fundamental and applied research. Governments may offer tax credits to companies that invest in R&D in fields like sustainable agriculture or renewable energy. It may entice businesses to spend money on innovative, environmentally friendly technology and goods [44]. The adoption of environmental standards and laws is another crucial issue. These regulations impose strict minimum criteria for environmental performance, such as those governing emissions or energy use. By establishing these criteria, governments may encourage firms to adopt more environmentally friendly practices and technology. Additionally, it helps level the playing field for companies that need to meet the same environmental standards [44].

Additionally, governments may assist eco-innovation financially by offering grants and loans. It can help companies overcome the start-up expenses of creating and adopting new technology or procedures. To assist in developing a market for these goods and promote acceptance, governments can also offer subsidies for environmentally friendly items such as renewable energy. Finally, public policy can contribute to individual awareness-raising and

encouraging sustainable conduct [45]. Campaigns for public education and financial incentives for families to adopt more sustainable behaviors, such as recycling or taking public transit, can be included in this.

When it comes to fostering global eco-innovation through public policy, there are several key themes that policymakers should consider [46- 47]. Offering incentives is a crucial component of eco-innovation programs [46]. Companies that invest in eco-innovation may be eligible for tax rebates, subsidies, and other financial rewards from the government [48]. Furthermore, laws requiring firms to report their environmental impacts and practices can aid in leveling the playing field for enterprises that prioritize sustainability. Regulations and standards are also necessary for promoting eco-innovation. Governments may establish a market for environmentally friendly goods and technology by establishing standards for emissions, energy efficiency, and other environmental criteria [47].

By increasing demand for eco-friendly goods and services, policies supporting sustainable consumption can contribute to eco-innovation advancement. It may entail advocating for sustainable lifestyles and educating customers on the effects of their decisions on the environment [46]. Promoting eco-innovation also requires government, business, and academic cooperation. A culture of eco-innovation that benefits everybody may be created with the support of policies encouraging collaboration [41], where such policies can make it easier to share ideas and resources. As the key to eco-innovation, promoting R&D entails encouraging the creation of new technology and creative solutions to environmental problems and sponsoring fundamental and applied research [12, 34].

2.4 Measuring Eco-Innovation

Many effective methods exist to measure eco-innovation [49], including surveys and digital and patent analysis (Kemp et al., 2019). The effects of eco-innovation may also be calculated directly from changes in resource productivity and efficacy [45].

De los Rios and Tukker (2008) mentioned that evaluating how much innovations help sustainability and environmental protection is a part of measuring eco-innovation. Garcia-Granero et al. (2020) provide a comprehensive analysis of measuring eco-innovation dimensions [49]. Such measures include environmental performance indicators, patent analysis, and surveys on energy effectiveness, water consumption, waste management, and greenhouse gas emissions [49]. Environmental performance indicators may be used to pinpoint areas of an organization's eco-innovation where it is succeeding and where there are opportunities for improvement [49]

Patent analysis is another way of gauging eco-innovation. Intellectual property, such as novel inventions, procedures, and goods, is legally protected through patents [50]. Such metrics can identify geographical regions where eco-innovation occurs and the categories of inventions created by analyzing patent data [50]. Analyzing patents can shed light on the technological advancements being made in eco-innovation.

Various techniques can assist decision-makers and other stakeholders in assessing the efficacy of eco-innovation programs and highlight areas that require more effort [49]. In more developed countries, eco-innovation focuses beyond adopting environmental technologies, and the transition goes from investing in pollution control to addressing recycling systems and cleaner production processes [5]. The rationale that motivated the current research sits firmly on the need for businesses to engage in eco-innovation to reduce the impact of climate change and transition to systems with low carbon emissions, thus, less ecological footprint. In addressing the questions posed earlier, we explore the role of government policy in encouraging creative thought and action,

the current policy instruments employed by countries, and the significance of public policy in influencing eco-innovation within SMEs.

3. Methodology and Data

A qualitative methodology is adopted for this study, considering its suitability for analyzing the complex nature of eco-innovation policies across different countries. The research focuses on examining current policy instruments influencing innovation in the ecosystem. Specifically, the focus is on SMEs within a sample of selected countries based on their demonstrated commitment to sustainable and environmental issues and data availability in English. Including countries like members of the European Union, Japan, China, the United States of America (US), Brazil, the United Kingdom, and Thailand provides a diverse and comprehensive overview of policy approaches. This covers varying economic profiles and challenges across the supply chain. Qualitative methodology is appropriate for this research as it allows for in-depth exploration and understanding of policy contexts, stakeholders' perspectives, and the intricate interactions between different factors shaping innovative initiatives [47]. The study relies on thematic analysis to capture the depth and complexity of policy landscapes, allowing for critical interpretations and insights into the dynamics of eco-innovation promotion at the national and global levels. Table 1 provides an overview of each country and the union of countries (the EU), including GDP per capita and populations.

3.1 Data Collection Process and Criteria

Sources for this research were selected using the PRISMA model. The model was chosen for its systematic approach to literature selection, ensuring transparency, rigor, and replicability in

the research process [52]. The selection criteria for countries included in the study were carefully established to ensure relevance and representativeness. To this extent, countries were selected based on their willingness to discuss climate change and environmental issues, indicating a commitment to addressing sustainability challenges. Additionally, the availability of data in English was considered to facilitate comprehensive collection and analysis. This criterion was essential for ensuring accessibility to relevant policy documents and literature for the study. The selected countries covered a diverse range of geographical regions and economic contexts.

The collection process involved thoroughly evaluating policy documents shown in Figure 1 from 2010 to 2022 over ten years. This timeframe was chosen to capture recent developments and trends in eco-innovation policies while allowing for a comprehensive analysis of policy evolution. Various sources were utilized to gather relevant data, including academic articles, books, reports from reputable international organizations like the United Nations (UN) and the European Union (EU), and government policy reports. Online databases like SCOPUS and Web of Science were also consulted to review the existing literature comprehensively. Including diverse sources helped triangulate data and capture multiple perspectives on policies.

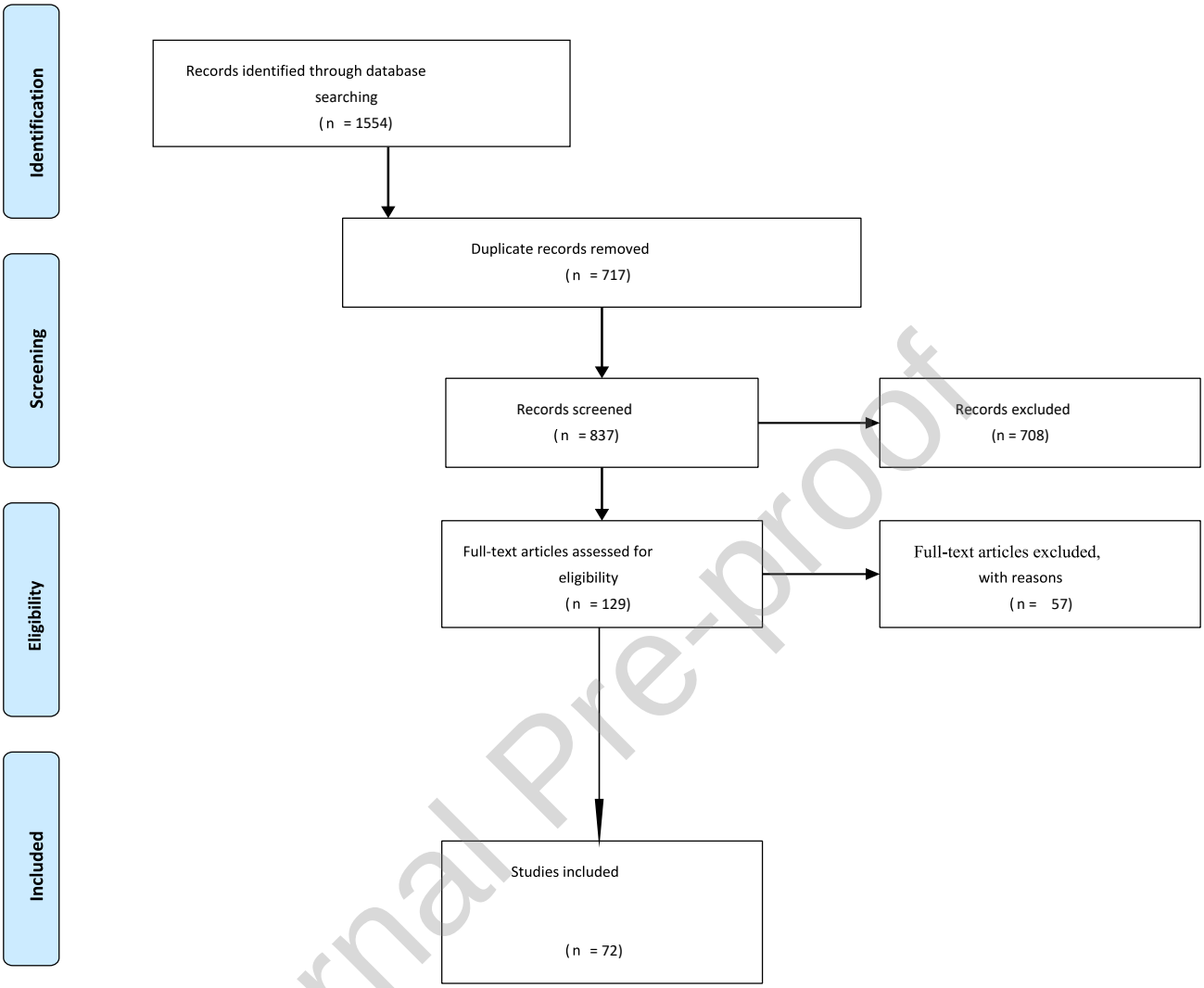

Fig. 1 PRISMA diagram

The inclusion and exclusion criteria were carefully defined to ensure the selection of relevant and high-quality sources for analysis. Inclusion criteria focused on the relevance of policy documents to eco-innovation and sustainability and their alignment with the research objectives. Policy documents from the selected countries were included if they explained the initiatives, strategies, and outcomes. Exclusion criteria were applied to filter out sources that did not meet the predefined criteria or were deemed irrelevant to the research focus. For example, policy documents

that primarily addressed topics unrelated to the research or were unavailable in English were excluded from the analysis. The research maintained methodological rigor by adhering to explicit inclusion and exclusion criteria, ensuring that sources that contributed substantially to the study objectives were selected.

3.3 Validity and Reliability

The reliability of research findings is protected through strict protocols adopted during data collection and analysis. A complete study of recommended policy documents, research articles, and reports from trustworthy international organizations was needed to collect information on eco-innovation policies. This thorough literature review aimed to ground the research based on reliable sources while accommodating as many perspectives as possible. In addition to that, different sources of data and the confirmation of results in terms of triangulation classification strengthened the reliability of the study.

Table 1: an overview of the public policies analyzed

Country	**Population (approx)**	**GDP per capita US$ 2022**	**Overview of the policy landscape**
European Union	447. million	41,037	One of the largest and most diversified economic blocs of 27 states. Policies committed to sustaining the environment and innovations
Japan	126 million	33,824	An industrialized is known for its most sophisticated technological landscape. Limited natural resources but committed to eco-innovation through policies that favor energy efficiency, waste reduction, and sustainable resource management.

China	1.4 billion	12,720	Rapid industrialization has raised issues about the sustainability of the environment. Current policies are leaning towards more green development, including investment in renewable energy and emission reduction targets. Its policies have solid global repercussions.
United States of America (US)	331 million	76,330	One of the world's largest economies. The US National Environmental Protection Agency assures all areas of government that environmental issues are considered before making changes that may affect the environment. The NEPA also develops and enforces regulations.
Brazil	213 million	8,918	Brazil is the largest country in South America, and its policies have a far-reaching impact on the Amazon rainforest and global biodiversity. Eco-innovation in Brazil focuses on sustainable agriculture and conservation.
UK	68 million	46,125	A former member of the EU, the UK has set very ambitious climate goals.
Thailand	69 million	6,910	Despite being a developing nation, Thailand's eco-innovation policies focus on sustainable tourism, renewable energy, and waste management.

Source: GDP data (World Bank 2023). Policy details: NEPA, USA (2023), Global Economic Forecasts: Euromonitor International, 2020.

To capture a holistic understanding of each country's policy landscape, this research relies on various data sources, including publicly available government and non-governmental organizations' reports, statistics, and databases, as well as journal articles, studies, and other publications. Martins et al. (2018) posit that the benefits of conducting research employing

secondary data include: firstly, researchers can access a wealth of previously gathered information and quickly produce pertinent policy variables [51]. Secondly, the investigator can expedite the research process by eliminating the need to wait for extended periods to gather data. As a result, the researcher can skip the data collection phase and go straight to the data analysis phase. (This is advantageous when analyzing fast-changing issues such as innovation and environment, as is the focus of the current study.) Thirdly, secondary data are typically available for a bigger sample size, and datasets are also supplied with weights or inflation factors. Therefore, the researcher can use statistical methods to produce weighted estimates encompassing a whole nation or industry [51].

To this end, data was collected through a comprehensive policy review. The review involves systematically searching and analyzing existing studies, articles, and reports on the research topic. In choosing the countries associated with this study, the criteria included the availability of reports, policies, and papers published in English and the countries' public commitment to eco-innovation and made significant strides toward environmental sustainability. The research was conducted consistently across all data collection techniques and participants to ensure dependability. This data complements the literature review presented earlier, providing a broad understanding of the role of government policy in fostering eco-innovation, the policies employed by different countries, and the importance of public policy on innovation and SMEs.

The countries searched for and evaluated were selected using the predefined criteria, which included the presence of English language documents and the countries' commitment to eco-innovation and environmental sustainability. In the qualitative data collection framework, the research requires consistency in criteria across all instruments and participants. It is essential to minimize bias and ensure that the findings are replicable.

3.4 Data Analysis

Thematic analysis was used to examine the information gathered during the policy review. The qualitative technique for finding, analyzing, and reporting data patterns is the thematic analysis and has been employed in similar studies [10]. The data was coded into themes and sub-themes for the data analysis. The research questions were then addressed using the themes and sub-themes. The gathered information was arranged into broad categories aligned with the study's questions. The data was then examined for patterns and trends within the sub-themes once the themes were divided into sub-themes, as shown in Figure 2. As for the biodiversity protection theme, critical thematic analysis would be the best way to fulfill the third research objective. It is because vital thematic analysis is a way to find, organize, and offer meaning (themes) or ideas (patterns) across a dataset [52]**.** Another benefit, especially regarding education and instruction, is that it is a technique rather than a comprehensive approach. Unlike many qualitative methodologies, this approach is not constrained by a specific epistemological or theoretical framework. This feature renders it an exceedingly adaptable approach, which is a significant benefit considering the wide range of tasks involved in learning and teaching [52]. A thematic analysis aims to discern significant or intriguing patterns in the data, referred to as themes, and utilize these themes to investigate the research topic or make assertions about a particular matter. A proficient thematic analysis goes beyond mere data summarization and provides interpretation and coherence. An often-encountered mistake is to utilize the primary interview questions as the central topics [53]. Usually, this indicates that the data has been condensed and arranged rather than examined in depth.

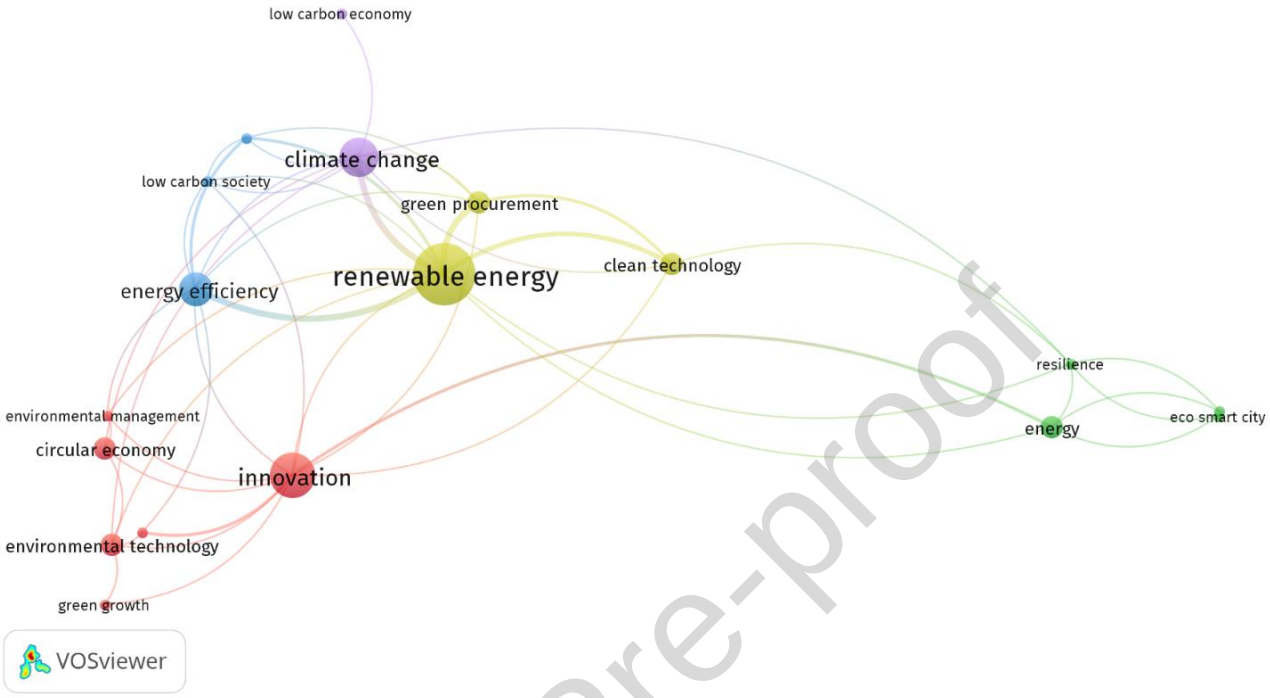

Figure 2: Policy Analysis based on thematic analysis approach.

4. RESULTS

The section presents the details of the eco-innovation policies from each country in the study, followed by the results from the thematic analysis. In assessing the effectiveness of public policies, clear metrics are essential for capturing their impact on sustainable practices and technological advancements. For instance, patent applications are a tangible indicator of innovation and technological progress within the eco-innovation domain [43, 72]. Policymakers can quantify the level of research and development activity in green technology by analyzing the number of patents awarded and the extent to which public policies stimulate innovation. Furthermore, monitoring green technology adoption rates gives valuable information about the practical execution of eco-innovation strategies [44]. Adoption rates reflect how organizations and

sectors embrace sustainable practices and incorporate environmentally friendly technologies. This metric can help assess the effectiveness of policy incentives and regulatory frameworks in encouraging the uptake of green technologies across various sectors. Furthermore, qualitative indicators from environmental impact assessments and sustainability performance indicators can provide a holistic understanding of the effectiveness of eco-innovation policies. The assessments evaluate the ecological footprint of projects and initiatives to provide valuable feedback on policy interventions' environmental benefits and drawbacks [49]. On the other hand, sustainability performance indicators explain the broader societal and economic implications of policies, including job creation, resource efficiency, and economic competitiveness. Thus, an integrated approach ensures a proper understanding of the outcomes of policies to facilitate informed decision-making for further progress towards sustainability goals.

4.1 Countries' eco-innovation promoting policies

The central theme of renewable energy is featured in most policies, followed by innovation and climate change. Renewable energy sources contribute to the provision of sustainable energy services, as well as the mitigation of climate change. Renewable energy sources and climate change mitigation investigate the current role and potential of renewable energy (RE) sources in providing energy services for a sustainable social and economic development trajectory. It includes assessments of available renewable energy resources and technologies, costs and benefits, barriers to scaling and integration, future scenarios, and policy options. For development to be sustainable, energy services must be reliable and have minimal environmental impact. Access to affordable

energy resources ensures sustainable social and economic development and provides essential services. It may imply using different strategies at various stages of economic growth.

Table 2 *Eco-Innovation Policies in Different Countries*

Country	**Policy**	**Importance of Eco-Innovation**	**Eco-Innovation Addressed**	**Theme**	**Sub-Theme**	**Source**
European Union	European Green Deal	Reducing greenhouse gas emissions	Climate Change and Biodiversity	Climate Change Mitigation	Energy Efficiency, Renewable Energy	European Commission
Japan	Cool Earth Partnership	Reducing greenhouse gas emissions	Climate Change and Biodiversity	Climate Change Mitigation	Energy Efficiency, Renewable Energy	Ministry of Foreign Affairs of Japan
China	Eco-Compensation	Improving bio-diversity	Water, Land, and Air Pollution	Pollution Prevention & Control	Ecological Restoration & Conservation &	National Development and Reform Commission
USA	Clean Air Act	Reducing greenhouse gas emissions	Air Pollution	Pollution Prevention and Control	Air Quality Standards, Emissions Control	United States Environmental Protection Agency

Brazil	Amazon Fund	Improving bio-diversity	Deforestation and Biodiversity Loss	Conservation of Biodiversity	Forest Conservation, Sustainable Use	Brazilian Ministry of the Environment
United Kingdom	Industrial Strategy	Promoting sustainable economic growth	Sustainable transportation, clean growth, and renewable energy	Pollution Prevention and Control	Energy Efficiency, Renewable Energy	Department for Business, Energy & Industrial Strategy
Thailand	National Science Technology and Innovation Policy	Enhancing economic competitiveness and resilience by increasing value added, value creation, and innovation by sector	National innovation system	Infrastructure in response to emerging issues	Lifestyle (education and health), resource and land, capacity building, waste management, environmental management, clean infrastructure, and	The Office of National Higher Education Science Research and Innovation Policy Council

	renewable energy.

The policies presented in Table 2 show that many nations (or Union of Countries) use various policy tools to promote eco-innovation. The *European Green Deal*, which includes energy efficiency and the utilization of renewable energy sources, focuses on mitigating climate change [46]. Japan's *Cool Earth Partnership* promotes renewable energy technology to lower greenhouse gas emissions [54]. Through ecological restoration and conservation initiatives, China's *Eco-Compensation* program targets pollution of the water, land, and air [55]. The *Clean Air Act* of the USA tries to reduce air pollution by regulating emissions and establishing standards for air quality [56]. The Brazilian *Amazon Fund* protects forests and preserves biodiversity [57- 58]. In Thailand, there is policy-based evidence to support the broad focus on innovation and technology across all sectors to support the development of the nation's innovation systems and infrastructure. The *National Science, Technology, and Innovation* (STI) Act 2008 developed the National Science, Technology, and Innovation Policy and Plan for 2012–2021. It outlines critical issues affecting the development of the STI Act (2008) that will better serve Thailand's economic and social needs. In addition, under the 20-year national energy efficiency plan, the Thai government has supported the development of energy efficiency, renewable energy utilization, green energy procurement, and energy-saving potential. Thailand's Twelfth National Economic and Social Development Plan (2017 – 2021) focuses on promoting green growth and industry and utilizing innovative wastewater and solid waste management technology to manage an integrated urban environment.

Overall, national strategies encompass a range of goals, including transitioning from the demonstration phase to commercialization in areas such as carbon capture and storage or micro

combined heat and power generation, enhancing consumer awareness of packaging, establishing technical standards for electric cars, and creating a significant presence in combined heat and power generation. These national strategies encompass a broad spectrum of policies, including but not limited to environment, science and technology, industry, transport, competition, and energy policies. They utilize a wide range of tools and initiatives, encompassing support for research and development and activities to create new markets and promote exports. Public authorities undertake these initiatives at national and local levels and provide insights into the appropriate division of responsibilities between them. Roadmaps offer a structure to evaluate the consistency of these policies. There is a noticeable difference between the policies implemented in European countries and non-European countries regarding eco-innovation [57-58]. European countries primarily encourage eco-innovation development through measures such as research and development support. On the other hand, non-European countries place greater emphasis on generating demand for eco-innovation by implementing performance standards.

4.1 Thematic Analysis of Eco-Innovation Policies

Thematic analysis is a technique used to analyze qualitative data by carefully examining the data and identifying recurring patterns to identify underlying themes. Reflexivity is a dynamic process in which the researcher's perspective plays a central role in interpreting the data [51]. Themes and sub-themes of eco-innovation policies were found through thematic analysis. The topics covered include biodiversity protection, pollution prevention and control, and climate change mitigation. Each subject has several sub-themes, such as sustainable use of biodiversity resources, air quality standards and emissions management, and energy efficiency and renewable energy.

This study shows the various strategies nations use to encourage eco-innovation. Climate change, pollution, and biodiversity loss are just a few of the environmental challenges addressed by the policies in this study. To shed light on the various strategies nations use to promote eco-innovation, the study also identified topics and sub-themes connected to eco-innovation policies. Fundamentally, this study's thematic analysis of eco-innovation policies reveals various approaches countries employ to address significant environmental issues on biodiversity conservation, pollution management, and global warming mitigation. The sub-themes identified give details on how the specific measures were undertaken in line with each of the broad themes.

5. DISCUSSION

The thematic analysis of the review of the policies, reports, and literature related to eco-innovation in the seven countries/Unions shed light on the role of public policy in fostering innovative thought and activity. Reviewing the policy instruments nations use to promote eco-innovation is also closely linked to public policy for SMEs. While some renewable energy technologies are primarily used within large-scale (centralized) energy networks, others can be deployed at the point of use (decentralized) in rural and urban environments. Equally, many renewable energy technologies have reached a significant level of technical maturity and are widely used; others are still in the early stages of commercial deployment and technical maturity. In theory, the potential for renewable energy is far greater than the total energy consumed by all of Earth's economies. Similar to Ojekemi and Ağa [31], the findings from this research confirm the impact of eco-innovation on renewable energy.

The value of the global technical potential of renewable energy sources is reflected in our policy analysis with no evidence of a slowdown. Research has consistently shown that the global

technical potential for renewable energy is significantly higher than the worldwide energy demand, both now and in the future. Of all the renewable energy sources, solar energy has the most significant technical potential; however, all of them have considerable potential. The deployment of renewable energy is likely to decline given the sheer magnitude of the global technical potential for such energy sources, confirming the recent findings by Hye et al. [26]. Renewable energy sources, like solar and wind power, are erratic and may not always be dispatchable when needed. Even though renewable energy benefits all forms of energy, some have comparatively lower energy densities, so reducing the delivered energy required to supply end-use energy services is particularly important. In addition to mitigating the effects of climate change, renewable energy sources can improve local environmental and health outcomes, secure energy supplies and energy access, and promote sustainable and equitable economic development.

As is the case for most policy implications, challenges exist for adoption and successful implementation. The following are some of the current obstacles and issues preventing the widespread use of renewable energy: market failures, upfront costs, financial risk, lack of data, capacities, public and institutional awareness, perceived social norms and value structures; current infrastructure and current energy market regulation; inappropriate intellectual property laws; trade regulations; lack of amenable policies and programs; lower power of RE and land use conflicts.

In addressing the first of the three research questions posed by the current research, *what is the role of government policy in encouraging creative thought and action*? The analysis shows that there is an essential role for public policy. Public policy is vital in fostering innovative thinking and action in eco-innovation. Governments use financing, tax incentives, and regulations as policy tools, and regulations can aid in establishing norms and enforcing adherence to environmental regulations [59]. To build an innovation culture, the government can also encourage

cooperation between firms, researchers, and public organizations [60]. From the data analysis, the current study finds that, motivated by a range of factors, some governments have successfully implemented various Renewable Energy policies to address these different aspects of RE integration into the energy system. In recent years, these policies have accelerated the growth of renewable energy technologies. Under most circumstances, increasing the share of renewable energy in the energy mix will necessitate policies that stimulate systemic changes. Government policy, the declining cost of many renewable energy technologies, changes in fossil fuel prices, and other factors have all contributed to a continued increase in the use of renewable energy to address the root cause of climate change [61- 62]. Geoengineering solutions have been proposed to address climate change, such as changing the Earth's heat balance by increasing surface albedo (reflectivity) or reflecting incoming solar radiation with high-altitude mirrors or atmospheric aerosols. It has also been proposed that ocean fertilization with iron could increase CO2 absorption from the atmosphere [63- 64].

As evidenced by the EU, Japanese, and USA policies, governments can provide individuals and organizations engaged in creative activities with financial incentives. It can offset innovation costs and make it more feasible for individuals to pursue innovative ideas. By investing in education, culture, and infrastructure, governments can foster an atmosphere conducive to creativity. It can foster an atmosphere where individuals can express themselves and experiment with new ideas. Governments can eliminate obstacles to creativity by reforming intellectual property laws, reducing regulation, and making it easier for individuals to launch businesses. It can help to level the playing field for creative individuals and companies.

Moving to the specific instruments, the second question asks, what are the current policy instruments employed by countries to foster their country’s and, ultimately, global eco-innovation?

From analyzing the policy landscape in the seven countries/blocs globally, we find that different nations use several policy tools to promote eco-innovation. For instance, Japan and some EU countries, such as Germany and Denmark, have enacted technology-specific policies focusing on certain eco-innovations. In contrast, countries like the UK and Sweden (part of the EU) have enacted market-based regulations like carbon pricing and emissions trading [65-66]. Additionally, nations like China and the United States have developed innovation clusters and technology parks to encourage cooperation between firms, scholars, and governmental institutions. Depending on the nation's political, economic, and environmental settings, these programs have varying strengths and limitations, which leads to the third and final research questions on exploring the significance of public policy in influencing eco-innovation within SMEs.

The literature and policies studied emphasize the significance of public policy for SMEs and innovation. By lowering their expenses, boosting businesses' competitiveness, and enhancing their environmental performance, eco-innovation policies may help SMEs greatly. To increase eco-innovations, the government may also give SMEs access to funding, technical help, and networks [67]. Public policy may also help SMEs and other stakeholders, including universities and research institutes, transmit information more quickly so that eco-innovations can emerge and spread.

Public policy can play a significant role in fostering innovation and SME development, as seen in the policy European Green Deal from the European Union. Existing laws that safeguard the prevailing centralized production, transmission, and distribution system still need to be put in place in the European Union, making it challenging to implement alternative technologies like RE, which is to review and amend current laws and regulations. The first step is introducing RE technologies, particularly for integrating them into the electric power system. SMEs are frequently

the source of new ideas and innovations [68], though they often need more means to develop and commercialize these concepts without external support. By understanding the function of government policy, we can better comprehend how to promote eco-innovation and sustainable development.

Policies promoting eco-innovation typically undergo gradual development and change over extended durations, making it challenging to sustain consistency over time. As priorities and needs change, reviewing and adjusting instruments accordingly becomes necessary. Furthermore, local authorities actively promote and endorse eco-innovation [69]. They have acquired the ability to tackle environmental issues at their own level and view environmental goods and services as new catalysts for economic expansion. Collaboration based on a more comprehensive comprehension of the distinct functions of the various tiers of government is necessary at all levels.

It is imperative to establish effective collaboration and synergy between the realms of research and industry. The process of implementing or putting into action new knowledge is equally important as the process of creating or acquiring that knowledge. The private sector is the primary means of deployment, both within a country and across borders (through trade and foreign direct investment). This has also been mentioned by Guo et al., 2018 [44].

Engaging in international cooperative research during periods of market uncertainty allows for the pooling of development risks and information sharing. Further knowledge could be acquired regarding the suitable instruments, timing, and risks associated with (international) collaboration for eco-innovation while considering perspectives from the environmental, scientific, industrial, and competitive domains [70- 72].

Governments can essentially borrow from successful innovative approaches worldwide. For instance, the Renewable Energy Directive (RED) in the EU offers a remarkable case study demonstrating the efficacy of policy frameworks in driving eco-innovation. Adopted in 2009, the directive sets binding targets for renewable energy usage across EU member states, aiming for 20% of gross final energy consumption to come from renewable sources by 2020 [73]. This directive has catalyzed significant advancements in green technologies. Countries within the region have implemented various strategies to meet these targets. The initiatives include investments in wind, solar, and biomass energy projects and promoting energy efficiency measures [32-35]. As a result, RED has spurred innovation in renewable energy technologies, leading to the development of more efficient and sustainable solutions for energy generation and consumption [73]. Japan's Cool Earth Partnership also aims to address climate change and promote sustainable development by supporting developing countries adopting low-carbon technologies [63,66]. Through this initiative, the nation has invested in renewable energy, energy efficiency, and sustainable transportation projects in various developing nations. The country has encouraged the adoption of eco-friendly technologies while simultaneously promoting knowledge transfer and capacity building in partner countries [64- 65]. This collaborative approach emphasizes the significance of international collaboration in promoting eco-innovation, particularly in tackling global environmental concerns.

These case studies offer essential information for countries seeking to adopt an innovative approach to address environmental concerns and promote sustainable development. First, they emphasize the importance of clear policy frameworks and goals in promoting eco-innovation. Governments may encourage investment in green technologies and foster eco-innovative activities by setting ambitious targets and offering incentives for innovation. The case studies also highlight

the importance of collaboration and knowledge sharing in advancing eco-innovation. Countries can benefit from international partnerships and cooperation agreements to access resources, expertise, and best practices in eco-innovation. Additionally, these case studies emphasize the need for long-term commitment and continuity in eco-innovation policies. Sustainable development requires consistent efforts and investments over time, and countries should prioritize policies that promote continuous improvement and innovation in environmental technologies.

5.1 Limitations of the Study

It is worth noting at this point that, like all research, limitations do exist. First, only policies from nations with a public commitment to eco-innovation were included in this study. The results might not apply to other countries that have not made eco-innovation a priority. Second, the research examined English-language policies, reports, and literature, which could have left out literature in other equally essential languages.

5.2 Future Research Direction:

1. **In-depth Case Studies**: By providing more in-depth country or region-specific case studies as a complementary analysis, it is possible to give a better understanding of the contextual factors that act as a driver for eco-innovation policy development and implementation. Through case studies, researchers can investigate the linkages between the policy framework, institutional dynamics, and the socio-economic factors influencing eco-innovation interventions.
2. **Stakeholder Perspectives**: By putting in place mechanisms that enable stakeholders, like small and medium-sized enterprises (SMEs), government agencies, academic institutions, and civil society organizations, to share their perspectives, we will have a better

understanding of the challenges and possibilities revolving around eco-innovation. Through involving various stakeholders, future research is meant to provide a ground for successful actions in sustainability.

By addressing these limitations and embracing future research directions, scholars can advance our understanding of the role of public policy in promoting eco-innovation and sustainable development on a global scale. Close cooperation between the disciplines and regions to solve fundamental environmental problems will be pivotal.

6. CONCLUSIONS

This study sheds light on various nations' eco-innovation policies. The thematic analysis found that government policy is vital in fostering innovative thinking and action towards eco-innovation. Public policy is crucial for supporting SMEs' eco-innovations. Different nations use different policy tools to promote eco-innovation. Policymakers can use these findings to develop efficient measures to encourage SMEs' expansion and eco-innovation. This study has determined the significance of government policy in nurturing innovative thought and action towards eco-innovation through theme analysis of policy landscape and literature evaluation. In line with previous research by Mahmood et al. (2020), our study finds that nations with explicit public policies on eco-innovation have advanced significantly in environmental sustainability [68]. The current study adds to the body of knowledge on governmental initiatives that support eco-innovation and identifies policy tools used to promote eco-innovation. The study highlights the the significance of public policy on SMEs and eco-innovation; the added value of such eco-innovation policy interventions is important contributors to economic development supporting the UN’s global goals (SDGs) and job creation.

The study also finds that Government initiatives that provide SMEs with resources and encourage eco-innovation positively affect their capacity for sustainable development. These findings support others' observations that facilitating small and medium-sized enterprises (SMEs) with resources and promoting eco-innovation benefit their ability to achieve sustainable development [69-71]. Furthermore, this research emphasizes the necessity for public policies that offer resources and incentives for innovation to promote SMEs. SMEs are a vital source of innovation and crucial to attaining sustainable development objectives. Therefore, while creating policies to encourage eco-innovation, authorities should consider the demands of SMEs.

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Ethical Statement

This research has been conducted by using the secondary data from reliable sources. There are no human participants involved in this research.

Funding Acknowledgement

This research has been funded by International College, Khon Kaen University, 123 Mitrphap Road, Khon Kaen 40002, Thailand

Author Contributions:

Authors participated in the drafting of this manuscript as individual experts in their fields, and are solely responsible for the contents. All authors have read and agreed to the published version of the manuscript.

Declaration of Competing Interest

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