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The State and the promotion of sustainability through Eco-innovation

O Estado e a promoção da sustentabilidade através da Eco-inovação

El Estado y la promoción de la sostenibilidad a través de la Ecoinnovación

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Abstract: This paper investigates some of the specificities and barriers to eco-innovation described in the literature and demonstrates (through the presentation of concrete examples) how specific public policies can overcome them, promoting forms of sustainable development. It is observed that public policies can reduce obstacles to eco-innovation, such as high initial costs, regulatory uncertainties and cultural resistance. The analysis of different international cases reveals that tax incentives, strict environmental regulations, R&D support programs, education and training, as well as international cooperation are essential to overcome these barriers. The results indicate that well-designed public policies not only reduce the costs and financial risks associated with innovation but also correct market failures and promote competitiveness and long-term sustainability. It is concluded that, despite the difficulties, the opportunities for eco-innovation are vast, as well as benefits that include the growth of the green market, technological innovations and strategic partnerships, highlighting the need for public policies adapted to the specificities of eco-innovation.
Keywords: Eco-innovation; Public Policies; Sustainability; Sustainable Development

Resumo: Este artigo investiga algumas particularidades e barreiras à ecoinovação descritas na literatura e demonstra (por meio de apresentação de exemplos concretos) como políticas públicas específicas podem superá-las, promovendo formas de desenvolvimento sustentável. Observa-se que políticas públicas podem reduzir obstáculos à ecoinovação, como altos custos iniciais, incertezas regulatórias e resistência cultural. A análise de diferentes casos internacionais revela que incentivos fiscais, regulamentações ambientais rigorosas, programas de apoio à P&D, educação e capacitação, bem como cooperação internacional são essenciais para superar essas barreiras. Os resultados indicam que políticas públicas bem elaboradas não apenas reduzem os custos e riscos financeiros associados à inovação, mas também corrigem falhas de mercado e promovem a competitividade e sustentabilidade a longo prazo. Conclui-se que, apesar das dificuldades, as oportunidades para a ecoinovação são vastas, bem como benefícios que incluem o crescimento do mercado verde, inovações tecnológicas e parcerias estratégicas, destacando a necessidade de políticas públicas adaptadas às especificidades da ecoinovação.
Palavras-chave: Ecoinovação; Políticas Públicas; Sustentabilidade;

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FRAS: conceptualization, formal analysis, validation, writing – original draft.
ERF: methodology, project administration, resources, supervision, validation, writing – review and editing.

Desenvolvimento Sustentável

Resumen: Este artículo investiga algunas de las especificidades y barreras a la ecoinnovación descritas en la literatura y demuestra (mediante ejemplos concretos) cómo las políticas públicas pueden superarlas, promoviendo así el desarrollo sostenible. Se observa que las políticas públicas pueden reducir obstáculos a la ecoinnovación, como los altos costos iniciales, la incertidumbre regulatoria y la resistencia cultural. El análisis de diferentes casos internacionales revela que los incentivos fiscales, las estrictas regulaciones ambientales, los programas de apoyo a la I+D, la educación y la capacitación, y la cooperación internacional son esenciales para superar estas barreras. Los resultados indican que las políticas públicas bien diseñadas no solo reducen los costos y los riesgos financieros asociados a la innovación, sino que también corrigen las fallas del mercado y promueven la competitividad y la sostenibilidad a largo plazo. Se concluye que, a pesar de las dificultades, las oportunidades para la ecoinnovación son amplias, al igual que los beneficios, que incluyen el crecimiento del mercado verde, las innovaciones tecnológicas y las alianzas estratégicas, lo que resalta la necesidad de políticas públicas adaptadas a las especificidades de la ecoinnovación.

Palabras clave: Ecoinnovación; Políticas Públicas; Sostenibilidad; Desarrollo Sostenible

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1 INTRODUCTION

Growing concerns about climate change and the urgent need to promote sustainable development have placed eco-innovation at the center of discussions on public policies and business strategies, with the implementation of new technologies and practices that reduce environmental impacts and promote sustainability (Montenegro; Carvalho, 2021, Díaz-Garcia et al. 2015). However, eco-innovation faces significant barriers that require an in-depth analysis of how specific public policies can effectively encourage it (Bossle, 2016, Pérez et al. 2024). Among the main barriers are the high initial development and implementation costs, regulatory uncertainty, cultural resistance, and the lack of comprehensive studies demonstrating the economic and environmental benefits of eco-innovation (Fernández-Muñiz et al. 2024, Marin et al. 2015).

The transition to a sustainable economy (Abreu et al. 2024) requires a significant reconfiguration of how natural resources are used and how economic activities are conducted, since technological innovation, combined with effective resource management, is crucial to achieving a "green" and sustainable economy (Loiseau et al. 2016), with the role of the State being fundamental in creating an environment that favors eco-innovation and encourages practices that minimize environmental impacts and promote resource efficiency (Montenegro and Carvalho, 2021). In light of this situation, this article seeks to explore, through a literature review and evaluation of cases described in this literature, how the State can overcome these barriers and encourage eco-innovation to address contemporary environmental issues, through effective and targeted public policies. It is argued that well-designed public policies can reduce the costs and financial risks associated with innovation, correct market failures and promote long-term competitiveness and sustainability, highlighting the need for specific approaches to overcome the inherent barriers to eco-innovation .

In this way, we hope to contribute to the discussion of the topic, since often (as shown by Mazzucato, 2014) "common sense" points to the State as an obstacle to innovation, in contrast to a more "proactive" stance by the private sector. We hope to demonstrate how this State action has been relevant for innovation and, particularly, for eco-innovation. This topic becomes particularly relevant in view of the perspective of energy transition (Carvalho et al. 2020) and manufacturing technology (Thier, 2021), which are fundamental for an environmentally sustainable model. Furthermore, factors such as the COVID-19 pandemic (Allam et al. 2022) and the Ukraine war (Zhu et al. 2024) demonstrate that humanity's path towards a low-carbon economy and a sustainable planet does not always receive the priority treatment that the situation demands, which seems to demonstrate the relevance of an approach that also uses public power tools and policies in the search for solutions.

2 ECO-INNOVATION AND THE ROLE OF THE STATE

The development, adoption and diffusion of innovations are essential processes for economic and social progress. However, innovation, by its very nature, involves uncertainties, risks and costs that often discourage private investment, with the role of the State being crucial in these "grand challenges" and environmental threats, such as "climate change, demographic, health and well-being concerns, and the difficulties of generating sustainable and inclusive growth" (Mazzucato, 2018). Innovation is one of the main factors of economic growth and social development, being responsible for increases in productivity, improvements in quality of life and the creation of new business opportunities (Cameron, 1996, Hasan and Tucci, 2010). Technological innovations, in particular, have the potential to transform entire industries and promote efficiency in various sectors of the economy (Freeman and Soete, 2008). Given the context of barriers to innovation, the State plays a crucial role in encouraging and facilitating the development, adoption and diffusion of innovations (Salerno and Kubota, 2008).

Eco-innovation involves the introduction of technological and practical innovations that aim not only to reduce environmental impacts but also to promote more efficient use of natural resources (Reid and Miedzinski, 2008), being essential for the transition to a low-carbon economy and playing a vital role in reducing the negative impacts of economic activities on the environment (Wang et al. 2020). The literature highlights that eco-innovation includes innovations in processes, products and business models that promote sustainability (Berkhout, 2005, Kemp, 2010), and companies that adopt sustainable practices can obtain competitive advantages, such as reducing operating costs, improving resource efficiency and accessing new markets (Bansal and Roth, 2000, Keijzers, 2002). Furthermore, eco-innovation is seen as a driver for sustainable economic development, promoting the creation of green jobs, increased productivity and long-term economic competitiveness (Horbach et al., 2014). In this case, public policies play a key role in creating an environment conducive to sustainable innovation and providing the necessary incentives for companies and industries to invest in clean technologies and sustainable practices (Lamperti, 2019, Demirel and Kesidou, 2011).

One of the main justifications for government intervention in promoting innovation is to correct market failures (such as positive externalities, asymmetric information, and public goods), which can lead to underinvestment in innovation if left exclusively to market forces (Porter and Linde, 1995). Innovations often generate benefits that go beyond direct financial returns for the innovating firm, such as knowledge creation and improved productivity in other sectors. However, these social benefits are not fully captured by firms, which can lead to insufficient investment in innovation, leading to the need for positive externalities in innovation processes. The government can intervene by providing subsidies, tax credits, and other incentives to align the social and private benefits of innovation (Porter and Linde, Op.Cit.). Similarly, asymmetric information between investors and innovators can hinder the financing of innovations, since it is not always

easy

to convince investors that innovations are viable and profitable, resulting in financing difficulties. For Cohen (2006), the State can mitigate this problem through credit guarantee programs and direct financing of R&D projects. Finally, many innovations, especially in areas such as scientific research and infrastructure technology, have characteristics of public goods, where it is difficult to exclude individuals from their benefits. This can lead to insufficient investment in such areas by the private sector, with the State being responsible for directly financing basic research and technological infrastructure to ensure that the benefits of these innovations are widely disseminated (Cohen, 1997).

In short, history shows that innovation is a key driver of long-term economic growth (Freeman and Soete, 2008), increasing productivity, creating new markets and improving international competitiveness. The authors indicate that the State can play an important role in promoting innovation as a strategy to stimulate sustainable economic growth, through a series of actions, including financing R&D activities, which are essential for the development of new technologies and innovative practices, providing resources for basic and applied research, supporting partnerships between universities and companies and creating centers of excellence in innovation. The State can offer tax incentives to companies that invest in innovation, such as tax credits for R&D expenses, tax deductions for investments in new technologies and subsidies for innovation projects, helping to reduce the cost of innovation and increase the attractiveness of investments in new technologies (Demirel and Kesidou, 2011). Finally, the creation of technological and innovation infrastructure, such as technology parks and startup incubators, is essential to support the development of new companies and the dissemination of innovative technologies, which can be supported by the State through investment in an infrastructure that facilitates innovation and collaboration between different actors in the innovation ecosystem (Freeman and Soete, Op.Cit.).

Furthermore, promoting sustainable innovation is essential to face the global environmental challenges and to ensure long-term economic development (Horbach et al., 2014) in different aspects, such as international competitiveness and environmental sustainability, helping to develop technologies that reduce environmental impacts and promote resource efficiency by promoting sustainable innovation through environmental regulations, incentives for green technologies and programs to support renewable energy and energy efficiency projects. According to the same authors, the State can also intervene to ensure that the benefits of innovation are widely distributed and that all segments of society have access to new technologies and development opportunities, such as access to new technologies, regional development and job creation.

2.1. Examples of eco - innovation policies in the world

The European Union is a reference in public policies aimed at sustainability and eco-innovation , as was the case with the Horizon 2020 Program, one of the largest research and innovation programs in the world, which allocated substantial resources to projects in environmental sustainability, energy efficiency and

innovation in green technologies, financing projects in areas such as renewable energy, waste management, resource efficiency, and encouraging collaboration between universities, companies and other institutions to promote sustainable innovation (European Commission, 2014), with a planned budget of 95.5 billion euros for the years 2021 to 2027 (Ricciardiello et al. 2021). In addition, the EU has implemented a series of strict regulations that encourage the adoption of sustainable practices throughout the economy, offering tax incentives and subsidies to companies that invest in green technologies and promoting knowledge and technology transfer through international cooperation programs (EUROPEAN ENVIRONMENT AGENCY, 2019).

China's innovation policy is characterized by strong government support, an integrated approach that involves collaboration between different sectors, and an emphasis on the practical application of developed technologies, standing out in the promotion of eco-innovation through ambitious public policies that encourage the development of green technologies and the adoption of sustainable practices. The 13th Five-Year Plan, for example, set ambitious targets for reducing greenhouse gas emissions, improving energy efficiency, and increasing the share of renewable energy sources in the country's energy mix (Zhou et al., 2019), offering tax incentives and subsidies for companies that invest in R&D in clean technologies and promoting collaboration between the public and private sectors for sustainable innovation (Li et al., 2018).

Brazil has promoted eco-innovation through a series of public policies that encourage research and development of sustainable technologies, such as the National Biofuels Program, which encourages the production and use of biofuels through tax incentives, subsidies, and regulations that promote sustainability throughout the production chain. In addition, the program supports research and development of new biofuel technologies, promoting innovation in the sector (Goldemberg et al., 2014). The Brazilian government has also implemented a series of policies to encourage renewable energy, including financing solar and wind energy projects, offering subsidies for the installation of solar panels, and creating support programs for startups that develop clean technologies. Such policies have contributed significantly to reducing greenhouse gas emissions in Brazil and promoting a more sustainable economy (Pereira et al., 2017).

3 METHODOLOGY

To investigate the particularities and barriers of eco-innovation and how specific public policies can overcome them, we adopted a methodological approach based on literature review and evaluation of real cases. The cases were selected based on their relevance, geographic diversity, documented impact and variety of sectors (energy, transportation, agriculture, etc.).

The case studies were selected based on criteria such as: (1) thematic relevance to eco-innovation public policies; (2) geographic and sectorial diversity (energy, agriculture, transportation, etc.); (3) availability of documented data on impacts and outcomes; and (4) representativeness of different models of government

intervention. The selection process aimed to ensure a balanced sample between developed and developing countries, allowing for meaningful comparisons across different contexts.

For each case, the following dimensions were analyzed: (1) Type of Public Policy (tax incentives, subsidies, environmental regulations, R&D support programs, etc.), (2) Barriers mitigated by public policy (such as high costs, regulatory barriers, lack of infrastructure, cultural resistance) and (3) results achieved (such as increased adoption of sustainable technologies and economic growth).

The analyses were conducted through triangulation of primary sources (official reports, government documents, statistical data) and secondary sources (academic articles, systematic reviews), focusing on identifying patterns of public policy effectiveness. Qualitative Comparative Analysis (QCA) was used to verify the recurrence of success factors, and content analysis was used to extract impact categories (economic, environmental, social).

For this study, a review of academic literature and reports from international organizations was carried out to identify relevant cases and obtain an in-depth understanding of the barriers and opportunities for eco-innovation. After this step, the cases were selected in order to identify a diverse set of cases that illustrate the effectiveness of public policies in promoting eco-innovation, followed by a detailed assessment of the aforementioned dimensions, using primary and secondary sources to collect quantitative and qualitative data. Finally, a synthesis of the information is presented, allowing a systematic comparison between the cases, facilitating the identification of patterns and the extraction of general lessons.

4 CHALLENGES AND OPPORTUNITIES FOR ECO-INNOVATION

Although promoting eco-innovation offers numerous advantages, there are several problems that need to be overcome to achieve a sustainable economy:

High costs and financial risks: The development and implementation of new sustainable technologies can involve high initial costs and significant financial risks. Many companies, especially small and medium-sized enterprises, may have difficulty in bearing these costs and assuming the risks associated with eco-innovation (Demirel and Kesidou, 2011; Horbach et al., 2014).

Regulatory and bureaucratic barriers: Complex regulations and bureaucratic processes can hinder the adoption of sustainable technologies. The lack of harmonization of environmental standards between different countries can also create obstacles to the dissemination of green technologies and international collaboration in sustainable innovation projects (Bernauer et al., 2006; Cohen, 2006).

Lack of infrastructure and resources: The absence of adequate infrastructure, such as renewable energy networks and sustainable transportation systems, can limit the adoption of innovative technologies. In addition, the scarcity of qualified financial and human resources can hinder the development and implementation of sustainable solutions (Li et al., 2018; Zhou et al., 2019).

Cultural and institutional resistance: Resistance to change, both at the organizational and cultural levels, can be a significant obstacle to the adoption of sustainable practices and technologies. Many organizations are still focused on traditional practices that prioritize short-term profit over long-term sustainability (Cohen, 1997; Hart, 1997).

Analysis of the data reveals that well-structured public policies tend to mitigate multiple barriers simultaneously. For example, programs that combine tax incentives with R&D support and environmental regulations are more effective in the adoption of green technologies. Furthermore, the data suggest that countries with a tradition of long-term strategic planning (such as Germany and Norway) achieve more consistent results in terms of sustainable innovation. The presence of monitoring and evaluation mechanisms also correlates with greater efficiency in the allocation of public resources.

These examples illustrate how different countries have adopted specific strategies to foster eco-innovation, overcoming structural and cultural barriers. Table 1 presents a summary of the main opportunities identified, relating them to specific public policies and their respective impacts, allowing a comparative view of the efforts made and the benefits obtained.

Despite the challenges, there are numerous opportunities to promote eco-innovation and sustainability. Below are real-world examples where government support has been crucial for eco-innovation to thrive:

4.1. Green market growth

The growing demand for sustainable products and services offers a significant opportunity for companies that invest in eco-innovation. The green market is expanding, with consumers increasingly aware of the environmental and social impacts of their consumption choices. Companies that offer sustainable solutions can gain a significant competitive advantage (Bansal and Roth, 2000).

Pro-Alcohol program, initiated in the 1970s, was essential for the development of ethanol technology as a renewable fuel. The Brazilian government provided subsidies and tax incentives for the production of ethanol from sugarcane, in addition to investing in infrastructure for the distribution and use of ethanol. As a result, Brazil has become a world leader in the production and use of biofuels, reducing its dependence on fossil fuels and promoting sustainability (Gomez et al. 2012).

State investment continues to play a crucial role in strengthening the use of ethanol as part of the energy transition in Brazil. In recent years, the government has intensified its efforts to foster the development of innovative technologies, such as hybrid engines and hydrogen cells that use ethanol. These initiatives are supported by public policies that aim to encourage research and technological development in the biofuels sector. Financing programs and tax incentives are part of this effort, ensuring that Brazil not only maintains its leading position in ethanol production, but also advances in the creation of clean and efficient energy solutions. Such measures are essential to consolidate the role of ethanol in the green market, promoting sustainability and reducing greenhouse gas emissions (Silva et al., 2023).

4.2.Technological innovations

Technological innovations such as digitalization, artificial intelligence and the Internet of Things (IoT) offer new opportunities for creating sustainable solutions. These technologies can be used to improve resource efficiency, reduce environmental impacts and promote sustainability in different sectors (Horbach et al., 2014).

In Germany, the Energiewende (Energy Transition) program is a successful example of promoting renewable energy. The German government implemented supportive policies, including feed-in tariffs, subsidies and tax incentives to promote solar and wind energy. These policies resulted in a significant increase in installed renewable energy capacity, making Germany a global leader in clean and sustainable energy (Belin et al., 2011).

Another example of how technological innovation supports sustainable development is Sundrop Farms. An innovative agricultural company based in Australia that stands out for its use of advanced technology to grow food sustainably, especially in arid regions. The project uses concentrated solar energy to desalinate seawater, which is then used to irrigate its greenhouses, eliminating the dependence on fresh water and fossil fuels for agricultural production. This system allows efficient cultivation even in environments traditionally unsuitable for agriculture due to water scarcity. In terms of financial support, Sundrop Farms has secured significant private financing and has also received incentives from the South Australian government. In 2014, the company obtained a loan of approximately A$150 million from the Commonwealth Bank of Australia to expand its operations, as well as local government support for infrastructure and development, although specific details of direct subsidies are not widely disclosed (Farms , 2024).

4.3.Partnerships and collaborations

Partnerships and collaborations between companies, governments and research institutions are crucial for promoting eco-innovation. Cooperation can facilitate the exchange of knowledge, the sharing of resources and the creation of joint solutions to environmental and economic challenges. Table 1 presents a summary of opportunities for eco-innovation described in the literature review. Such partnerships are essential for large-scale innovation and the implementation of sustainable solutions (Horbach et al., 2014).

The European Union’s Horizon 2020 project is an example of how international collaboration can promote eco-innovation. This research and innovation program, with a budget of almost 80 billion euros, funds projects that promote environmental sustainability, energy efficiency and technological innovation. Through partnerships between universities, businesses and other institutions, Horizon 2020 has accelerated the development and implementation of sustainable technologies across Europe (European Commission, 2014).

Similarly, the UK has implemented significant policies to encourage innovation in sustainability, with a focus on reducing carbon emissions and promoting clean technologies. These policies include grants for research and development, tax incentives for companies that adopt sustainable practices, and support for renewable energy projects (GOV.UK, 2024). A notable example is Waitrose’s initiative to use delivery vans

powered by biomethane from food waste. This project not only reduces the company's carbon footprint but also exemplifies the practical application of government policies to encourage sustainability. Although specific details about direct funding for Waitrose are not widely disclosed, the UK's policy infrastructure creates an enabling environment for such innovations (Waitrose & Partners, 2019).

4.4.Public support policies

Implementing effective public policies that encourage eco-innovation and sustainability can create a favorable environment for the development and adoption of green technologies. Such policies may include tax incentives, subsidies, environmental regulations, and R&D support programs. Well-designed public policies can stimulate investment in clean technologies and promote sustainable innovation in different sectors of the economy (Horbach et al., 2014).

The tax incentive program for electric vehicles in Norway is an example of how public policies can promote eco-innovation. The Norwegian government offers tax exemptions, access to dedicated lanes, and free parking for electric vehicles. These policies have resulted in a significant increase in the adoption of electric vehicles, making Norway one of the countries with the highest proportion of electric vehicles per capita in the world (Demirel and Kesidou, 2011).

The National Program for the Production and Use of Biodiesel (PNPB) in Brazil, launched in 2004, aims to promote the production and use of biodiesel as a sustainable alternative to fossil diesel. The program includes tax incentives, subsidies, and the mandatory blending of biodiesel into diesel sold in the country. As a result, Brazil has become one of the largest producers of biodiesel in the world, contributing to the reduction of greenhouse gas emissions and the promotion of sustainability (Gomez et al., 2012). The same authors cite the Program for the Incentive of Alternative Sources of Electric Energy (PROINFA) in Brazil, created in 2002, which aims to increase the participation of renewable sources in the Brazilian energy matrix. The program offers financial incentives and long-term power purchase agreements for wind, solar, and biomass energy projects, contributing significantly to the growth of installed renewable energy capacity in Brazil, promoting sustainability and diversification of the energy matrix.

While financial data is not always available in a standardized format, some cases allow for comparisons between effort and return. For example, the Horizon 2020 program invested approximately €95.5 billion between 2021 and 2027, resulting in hundreds of sustainable projects with a direct impact on reducing emissions and creating green jobs. In Brazil, the Pró-Álcool program has seen significant public investment since the 1970s, with returns in the form of global leadership in biofuels and reduced dependence on oil. Sundrop Farms in Australia obtained AU$150 million in financing, with returns in the form of sustainable agricultural production in arid regions. These data illustrate how government investment can generate long-term environmental and economic benefits.

Table 1: Summary of opportunities for eco-innovation

OPPORTUNITIES	DESCRIPTION	EXAMPLES	REFERENCES
Green market growth	The growing demand for sustainable products and services offers a significant opportunity for companies investing in eco-innovation.	Pro-Alcohol Program: Subsidies and tax incentives for ethanol production, making Brazil a world leader in biofuels. Current state investment program in hybrid engines and hydrogen cells that use ethanol.	Gomez et al., 2012 Silva et al., 2023
Innovations technological	Technologies such as digitalization, AI and IoT offer new opportunities to create sustainable solutions, improving resource efficiency and reducing environmental impacts.	Energiewende program in Germany: Support policies for solar and wind energy, resulting in a significant increase in installed renewable energy capacity.	Belin et al., 2011
		The Australian Sundrop Farms uses solar energy to desalinate water and grow food in arid regions, promoting sustainable and innovative agriculture.	Farms , 2024
Partnerships and collaborations	Partnerships between companies, governments and research institutions facilitate the exchange of knowledge, sharing of resources and the creation of joint solutions to environmental and economic challenges.	European Union Horizon 2020 Project: Financing sustainability projects through international partnerships, accelerating the development of sustainable technologies.	European Commission, 2014
		Waitrose uses biomethane from food waste to power delivery vans, promoting sustainable transport and reducing carbon emissions.	Waitrose & Partners , 2019
Public support policies	Effective public policies, including tax incentives, subsidies, environmental regulations and R&D support programs, create a favorable environment for the development and adoption of green technologies.	Tax incentives for electric vehicles in Norway: Tax exemptions and additional benefits resulting in high adoption of electric vehicles.	Demirel; Kesidou , 2011
		National Program for the Production and Use of Biodiesel (PNPB) in Brazil: Tax incentives and subsidies for biodiesel production, making Brazil one of the largest producers in the world.	Gomez et al., 2012
		Incentive Program for Alternative Sources of Electric Energy (PROINFA) in Brazil: Financial incentives for renewable energy projects, increasing installed capacity.	Gomez et al., 2012
		ABC Plan in Brazil: Credit lines and technical assistance for sustainable agricultural practices, reducing emissions in agriculture.	Gomez et al., 2012
		The National Environmental Program (PNMA I and II) strengthened environmental management in Brazil, promoting sustainable governance and community participation in the 1990s.	World Bank, 1989

Source: By the authors

Brazil also has one of the oldest initiatives in this area, the National Environmental Program (PNMA), launched in 1989 with the aim of strengthening institutional capacity for environmental management in Brazil. This program, supported by the World Bank, sought to integrate sustainable practices into public policies, promoting environmental conservation and the rational use of natural resources. PNMA I focused on institutional and legal aspects, while PNMA II, initiated in 2000, continued these efforts, increasing the emphasis on projects involving community participation and decentralized management of natural resources. Both programs were fundamental in establishing a solid foundation for environmental governance in the country, promoting integration between different levels of government and civil society for the implementation of effective environmental policies. Today, Brazil continues to implement environmental programs and policies that align with the initial objectives of the PNMA, but under different names and structures, reflecting the evolution of environmental and governance priorities (World Bank, 1989).

5 CONCLUSION

Eco-innovation plays a crucial role in promoting sustainability and the transition to a low-carbon economy. The State, through effective public policies, has a key role in creating an enabling environment for sustainable innovation and in promoting practices that minimize environmental impacts and promote resource efficiency. This article highlighted the importance of public policies for eco-innovation, discussed the main challenges and opportunities, and presented examples of successful policies in different economic contexts.

The selected cases illustrate how public policies can overcome specific barriers to eco-innovation and promote sustainability. For example, the Pro-Alcohol program demonstrates how tax incentives and subsidies can reduce the upfront costs and financial risks associated with eco-innovation, the Energiewende program illustrates how strict environmental regulations and incentives can promote the adoption of renewable energy, while the Horizon 2020 project highlights the importance of international partnerships and collaborations. Experience has shown that policies such as tax incentives, environmental regulations, R&D support programs, education and training, and international cooperation are essential to promote eco-innovation and address global sustainability challenges.

Despite significant advances in the field of eco-innovation, there are still several areas that offer opportunities for future research. One promising area is the analysis of the impact of specific public policies on different economic sectors, assessing how tax incentives and subsidies can be optimized to maximize sustainable innovation. Furthermore, the integration of emerging technologies, such as artificial intelligence and blockchain, in the promotion of sustainability represents an underexplored frontier that can revolutionize the efficiency of industrial and logistics processes. Another important gap is that of comparative studies between different regions and countries, which can reveal best practices and help in the adaptation of public policies

according to specific cultural and economic contexts. Furthermore, it is crucial to investigate the role of small and medium-sized enterprises (SMEs) in eco-innovation, since they often face unique challenges in terms of resources and access to financing. Finally, research on the interaction between public policies and sustainable business practices can provide insights on how to foster a culture of innovation within organizations, promoting structural changes that go beyond regulatory compliance. Exploring these areas will not only contribute to the theoretical development of the field, but will also provide practical guidance for policymakers, businesses and other stakeholders in the transition to a sustainable economy.

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