

ECO-INNOVATION AND SUSTAINABLE PRODUCTION IN DEVELOPING COUNTRIES. CASES COLOMBIA AND MEXICO

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Abstract

One of the main failures of innovation in developing countries is the difficulty that companies have to generate eco-innovations that address social, economic and environmental needs. Sectors such as manufacturing must permanently seek to reduce the negative impacts of their actions in order to generate sustainable benefits in society, as they protect the environment, make efficient use of resources and venture into global markets.

Based on descriptive documentary research, processes of efficient use of raw materials and energy efficiency in sustainable production are analyzed in manufacturing companies from two developing countries, Colombia and Mexico, around the creation of eco-innovations.

The results of the study show sustainable production activities in both countries, however, they do not generate eco-innovations despite the existence of indicators and policies that seek to measure and encourage sustainable innovation. Moreover, among the main difficulties is the lack of awareness of the eco-innovation's implications and benefits in the industry. This raises the need to articulate economic agents that affect eco-innovative processes with respect to common objectives, decrease economic and cultural barriers around sustainability as an axis for development.

Keywords: resource management, sustainable innovation, sustainable development, manufacturing industry, environment

1. INTRODUCTION

At a global level, there are great challenges to achieve the 17 Sustainable Development Goals (SDG) from its three dimensions: economic, social and environmental. In order to comply with the different goals, the countries require the participation and articulation between the different actors (civil society, companies, and the national and local government), contributing from the design and creation to the implementation of the agreed upon. The possible proposals that can be elaborated imply the articulated work between the actors.

Sustainable development articulates the economy, the environment and the society. The intersection of the three sets is sustainability; the social and environmental relationship expresses the balance that can be formed from a sustainable aspect; the social and economic relationship aims to achieve fairness; and the environmental and economic relationship seeks to achieve a balance through the involvement of the productive sectors [1].

Companies, one of the main economic actors, contribute to sustainable development according to their interests and the necessary methodology to achieve the established priorities, bearing in mind the possible impacts that may be generated and how to counteract them [2]. Their contribution to the SDGs can be defined by the philanthropic factor they have in the intention to improve the social and environmental conditions of the environment in which they operate; the search for initiatives and procedures where there is greater benefit and lower costs; and the development of product and service innovations [3].

In particular, sectors such as manufacturing in Colombia and Mexico impact sustainability from different patterns of production, consumption and innovations, in response to public policies that guide the scope of the SDGs, clean production processes and economic progress [4]. The industry in general faces challenges in social and environmental matters, in such a way that it requires the planning of changes in the whole production process, implementing eco-innovative processes, which contributes to the reduction of negative impacts, the environmental training of the consumer and the creation of innovations in a sustainable manner.

A term that has been gaining relevance at the macro and microeconomic level is that of eco-innovation.

Eco-innovation is the introduction of any new or significantly improved product (good or service), process, organizational change or marketing solution that reduces the use of natural resources (including materials, energy, water and land) and decreases the release of harmful substances across the whole life-cycle [5].

Eco-innovation raises the need to introduce changes in the production and consumption of goods and services, approaching sustainability [6]. It does not necessarily propose the creation of new products and processes but seeks to reduce environmental impact through the 6 pillars of a circular economy, including Recycling, Remanufacturing, Re-use, Repair, Sharing and Design [7].

It is proposed that eco-innovation is a way to consolidate a competitive, redistributive and sustainable economy, through a balanced use of resources, better production processes through which raw materials and energy are saved, as well as renewed products generate decrease in negative environmental impact, increase in the demand for goods and services and even an increase in productive employment [8].

The environment, being the key point of all the basic resources for the raw material of the manufacturing industries, implies the need to be protected to reduce the environmental footprint generated by the excessive use. The use of energy must also be taken into account because production is used widely and uncontrolled. Eco-innovations must be carried out by manufacturing companies in order to achieve economic and environmental objectives and reduce the negative impact, since it consists of the development of products and ways of working that contribute to sustainable development [9].

Despite the fact that the concept of eco-innovation originated in Europe by the OECD, it has acquired a global interest, including Latin America, since from an economic aspect competitive advantages are generated within companies since it entails the creation of new ideas, products and services, new business models, markets and opportunities, as well as savings in the costs of raw materials and energy and an increase in the technological level of companies, which impacts the added value [10];[7].

Eco-innovation requires a process of social awareness as the products and processes that give value to the client and the company and that effectively reduce the impact on the environment, depend on the demand for consumer goods and services [11], that is, eco-innovation goes beyond the environmental impact since it is a priority to highlight the tactic, the development approach and the relationship between producers and consumers [12].

In addition, sustainable production is a determining factor to achieve eco-innovation in companies, as it is an industrial activity that transforms raw materials into products with higher added value but seeks to minimize negative impacts on the environment by reducing materials, the consumption of energy and natural resources [13]. Sustainable production contributes to the reduction in pollution resulting from processes (CO₂ emissions), which implies a reduction in costs that the company would have to assume [14]. From the perspective of the manufacturing industry, the production must consider the re-manufacturing of manufacturing products, responsibly assume the management of the waste and make a decision-making of this last aspect with the intention of reducing the negative environmental impact [15].

According to the above, it is intended to understand the processes for the efficient use of raw materials and energy efficiency in order to achieve the sustainable production of the manufacturing industry in two developing countries, Colombia and Mexico, based on the premises of eco-innovation, in order to identify the actions that companies take to reduce their negative impacts and increase the consumption of their products. In Mexico, the manufacturing industry is led by the automotive sector, followed by

the food sector [16]; while in Colombia the main manufacturing industries belong to the oil refining sector, chemicals and rubber and plastic products, followed by the of chemical products and beverages [17].

The proposed objective is developed in four sections. The second exposes the research methodology. The third part presents the results found regarding the activities of companies for the scope of sustainable production, followed by the discussion process. Finally, some conclusions are presented.

2. MATERIALS AND METHOD

The research was developed through the documentary exploration of research articles, official documents of Colombia and Mexico and research work on the efficient use of raw materials and energy efficiency of sustainable production that are undertaken from the manufacturing industry. In terms of timing, the documents between 2010 and 2018 were selected.

Advanced searches were carried out in the databases EBSCO, Engineering Village, ScienceDirect, Scopus, Proquest using the terms "Resource management", "sustainable innovation", "sustainable development", "manufacturing industry", "eco-innovation" as search criteria "In both English and Spanish, limiting the search with the terms" AND Colombia OR Mexico ". For a total of 913 documents, when reviewing the abstract and following the central point of the investigation, a total of 151 documents were analyzed.

Table 1. Number of documents analyzed by Database

Database Keywords	EBSCO	Engineering Village	Science-Direct	Scopus	Proquest	Others
Sustainable Production	3	4	7	3	3	11
Sustainable innovation	0	1	3	11	2	20
Sustainable Development	6	7	1	14	7	43
Eco-innovation	0	1	2	1	4	1

3. RESULTS

After reviewing the information an important element that should be considered is the limited information available in academic journals about Colombia and Mexico about the search terms used. The documents analyzed in some cases are not for the purpose of studying the manufacturing industry, although they were considered since their results expose elements related to the sustainable development of the countries.

National public policies play an important role in the economic and environmental advance of companies in such a way that they promote the use of energy and the protection of the environment. In that sense, the government of Colombia was in charge of proposing the National Policy of Sustainable Production and Consumption in 2010, which raises the need to move towards a circular economy. One of the evidences highlighted by this policy is the cultural evidence and the change of thought that should be made around consumption, since the direct relationship between socioeconomic status and consumption poses a cultural problem of unsustainability (higher consumption, better position socioeconomic) [18].

In the Mexican case there is the National Strategy of Sustainable Production and Consumption of 2012, which diagnoses the main problem of the country, the growing consumer society which seeks its satisfaction in the increasing purchase of goods and services without real need to do so and without being aware of the social and environmental repercussions that this may entail [19]. This type of consumption generates in turn a production of excessive goods and services, increasing the pressure on natural resources and raw materials, leading them towards a path of depletion.

3.1 Efficient use of energy: biofuels

3.1.1 Colombia

Colombia is positioned as a leader in important sectors of the Latin American economy such as the agricultural sector and the chemical sector, which may mean an increase in its greenhouse gas (GHG) emissions. Because it is expected that more economic activity, more use of hydrocarbons and in this way more CO₂ emissions, it is of vital importance that actions are taken to encourage the reduction of CO₂ emissions through policies and technical strategies and economic ones that promote the use of technologies and processes that are clean and friendly to the environment [20].

Faced with this continuous challenge, the Colombian state has promoted biofuels as a strategy that would allow the country to reduce CO₂ emissions, direct the economy to energy self-sufficiency and the independence of hydrocarbons and would especially benefit agricultural and social development and the preservation of environment [21]. Through the aforementioned route, Colombia managed to position itself as one of the largest producers of biofuels in the Latin American region, manufacturing mainly palm oil, biodiesel and ethanol from sugarcane and cassava, which can replace 9% of the Diesel consumed mainly in the transport sector and reduce GHG emissions to the atmosphere by up to 89% [22]. The biofuels produced are being mixed with fuels of fossil origin, in order to generate a more efficient performance of them, reducing emissions of polluting gases and thus contribute to the independence of the petro-fuels [23]; [21].

Biofuels can be a biodegradable raw material substitute for petrochemical products in the chain of alcohol chemistry, for example, biodiesel are raw material to produce biodegradable detergents, however their main limitation is prices, in some cases, higher than those derived from biodiesel oil [22].

3.1.2 Mexico

In the review conducted it was possible to identify progress in relation to the use of non-renewable sources in Mexico, achieving an increase between 2014 and 2017 in the use of hydro energy of 12.9%, and 3% from other sources; however, non-renewable sources also increased (3% coal and 17% natural gas, although the latter represents 57% of total fuels) [24].

In contrast to the Colombian case, Mexico does not have a highly developed bioenergy market. The biofuels industry and its respective legislation is little due to competing with the subsidized prices of fossil fuels, which has not allowed the development of a more advanced biofuels industry. Mexico remains an economy without a true biofuel market. The supply of biofuels is very limited: there are no ethanol production plants to supply the needs of the economic sectors of the economy such as transport and all biodiesel projects have been closed or are stagnating, despite the existence of legislation that promotes the production of biofuels in the country [25].

The Mexican State' incentives to encourage the production of fossil biofuels were also based (as in the Colombian case) on the proposal to seek independence from fossil fuels; this is especially relevant since despite Mexico's extraction oil, most of it is exported and many times it has been necessary to import gasoline to supply its own market. In addition to this, the promotion of biofuels would result in a significant decrease in GHG emissions and promote economic development, especially in the most impoverished rural communities [25].

In Mexico, the use of energy by the industrial sector is enormous, as well as its possibilities to implement savings methods. Therefore, it can be affirmed that it is possible to implement climate mitigation strategies through the increase of energy efficiency focused on the industrial sector [26].

Mexico has a geographical position that represents an advantage for the development of renewable energy, such is the case of the Baja California peninsula, with a high level of radiation for the potential development of solar energy, in addition to the potential to generate wind energy and geothermal, for its position on a volcanic axis [27].

3.2 Sustainable production: evaluation based on life cycle analysis

3.2.1 Colombia

Regarding the analysis of sustainable production, it is possible to use the life cycle assessment (LCA) as an auxiliary due to two main reasons, on the one hand its use and constant increase as an instrument that allows to know the current state of the productive process of each company and on the other because this methodology encompasses the different phases within the productive activity such as design, supply, manufacturing and distribution of goods, thus offering a description of the phases of production. They are emphasizing sustainable practices.

In Colombia, [28] evaluated 14 companies in the coffee region of Colombia, obtaining heterogeneous performance in the different phases of the process, with design and manufacturing being the processes with the greatest attention towards sustainability, in contrast to the distribution phase that is the most lagging. This situation contrasts with that found in SMEs in the metal-mechanic sector in the departments of Caldas, Quindio and Risaralda, where the analysis does show sustainable actions on the distribution phase although it is emphasized that these are not part of the company's strategy, although they do produce a positive impact on the environmental, the economic and on the perception of the public towards the organization [29].

It is necessary to mention that in the reviewed bibliography there are other cases, apparently about sustainable production in Colombia, but that have been addressed in the previous section because they are cases related to the biofuels sector, widely disseminated in the country, proliferating in these texts the intervention in the phase of the productive process related to the supply, when venturing into new materials of greater energy efficiency and lower environmental impact.

3.2.2 Mexico

The application of the LCA tool in Mexican companies has been documented for the cement, mining, footwear, automotive and parastatal industries of the energy sector, driven mainly by the intervention of the international market [30].

In these cases, strategies for sustainable production have been implemented in different phases of the process. In the case of the cement industry, the intervention occurred in the supply when studying the substitution of a fossil fuel by waste with high caloric power that would allow to reduce the waste of this material in sanitary landfills, as well as to reduce the emission of contaminating compounds derived of the burning of fuel [31]. On the other hand, in the energy sector, the strategy focuses on manufacturing by improving the quality characteristics that impact on the efficiency of the barrel crude oil products [32], thus achieving a greater use of the product.

These examples are added to other documented cases such as the reuse of construction waste in the origin process [33] and the case of the automotive industry, where research by companies is carried out in the phase of design, on the efficiency and physical properties of materials, and the use of renewable energies [34].

On the other hand, actions such as the evaluations on the waste management system in Mexico City [35] are highlighted, where different alternate scenarios are compared for the final disposal of the waste, evaluating which would cause a lower environmental impact. This situation is particularly analyzed by [36] when evaluating the options for ending life for cell phones and [37] who address the case of systems for collection and reproduction of soft drink packaging. Although these cases focus on a later phase to the use of the product and do not correspond to a productive process, they are part of the supply chain and therefore it is the responsibility of the industrial sector that generates it, to design and implement sustainable strategies for the final disposition.

These cases are evidence of the existence of efforts aimed at a production with a lower environmental impact, from the industry, increasing the efficiency of the production process, reducing costs of materials and inputs or improving the properties of the product in order to make better use of the resources.

4. DISCUSSION

The review made it possible to identify common objectives that exist between Colombia and Mexico to achieve sustainable development, where the economic agents of government and companies undertake advance activities to reach the SDGs. Both economies seek to reduce economic and cultural barriers to achieve sustainable development through policies that promote and support the development of sustainable production. In this sense, manufacturing industries play a decisive role in the development of products, services and, processes that contribute to the reduction in environmental impact; however, the results presented allow the identification of sustainable activities in the productive processes but they did not identify that said activities were framed in a process of eco-innovation.

From the point of view of public policy, there is an interest to create a culture and knowledge about sustainability both in the producer and in the consumer, however, terms such as eco-innovation and sustainable innovation have not been incorporated in depth in the business environment and, therefore, have not been able to perceive its implications and benefits.

It is important to highlight that companies have a different behavior against sustainable production, which has been inserted into the economies through public policies. In culture, knowledge should be expanded and deepened not only for entrepreneurs but also for consumers who can contribute to production decision-making, know and understand the economic, social and environmental benefits that would be generated in such a way that create spaces to create eco-innovations in industries [38].

It is worth mentioning that, given that the transition towards sustainable production implies a change in the processes and paradigms of each company and/or industry, in addition to the creation of new skills, the use of new technologies and strategies for the organization, the realization of an analysis that allows to evaluate if in fact, the changes made place the company in a state of greater sustainability, being the analysis by life cycle a proliferating tool and whose application offers enough and specific information on the implemented improvements [39]. On the other hand, it is observed that, in the case studies, although the LCA methodology allows covering a chain of processes, the strategies implemented towards sustainable production are only focused on a specific section and are not carried out with a perspective holistic approach that could allow a greater approach towards sustainability [40].

Companies can see the benefits of following the policies in both countries, however, there is still no greater knowledge of this profitability that would not only apply to industries, but also to the social and environmental factor, generating greater protection for biotic resources and abiotic. For this reason, although there is an interest to achieve sustainable production and sustainable innovation, knowledge, and interest in applying eco-innovation to each industry or production factor is not very clear.

In relation to the industrial role in the efficient use of energy, the analyzed documents do not show applicable results in the use of unconventional energies in their productive processes, although it is important to mention that in Colombia, 76% of the total energy production comes from hydroelectric sources [41]; while in Mexico 80% of energy production comes from coal and hydrocarbons (oil, gas and condensates) in that order of participation, contributing to 80% of the total produced (Table 2).

Colombia has shown substantial improvements in the reduction of CO₂ emissions. There are incentives to make more and more progress in the biofuels industry and in other ways to reduce emissions by studying cases of countries whose economic growth has not been diminished by the commitment to sustainable development. In some articles, it states the need for intervention by national governments to encourage companies to adopt measures to reduce CO₂, confirming the initial premise of the few private initiatives to reduce these emissions. The suggested government instruments are, among others, taxes and controls on the prices of energy and fossil fuels (Table 3).

In spite of the problems faced by the Colombian sugar industry, several companies within the sector submitted to implement the Bonsucro certification, which seeks to reduce the amount of water used in their production processes by the sugar and ethanol industries, as well as the reduction of pollution in water sources [23]. On the other hand, Colombian producers of palm oil are motivated by internationally required strategies, they are predominantly economic. For these entrepreneurs, "sustainability" lies in

the scope of ecological value in the quest to achieve economic value [42], a value that would be sought in any other kind of industry.

The low level of Mexican bioenergy development is a situation that manifests itself in several of the articles reviewed. Direct regulation in the case of Mexican producers, understood as a system of permits, caps or licenses that are carried out in agreement with the companies involved, has given some positive results [43]. Carbon taxes are seen by producers as simple tools to increase state revenues, without the state lending sufficient support to the biofuels and clean energies industry [44]. Without adequate support to the biofuels industry and the privileged position of hydrocarbons in the Mexican economy, this industry could be economically unviable.

5. CONCLUSIONS

This approach to the current state of Colombia and Mexico on sustainable development shows how, in both countries, goals have been set and processes have been implemented to achieve them. It is perceived a contribution from the manufacturing sector in the construction of the context on which should be developed future strategies to achieve a sustainable industry. At the global level, the conditions under which the manufacturing industry operates have changed: competition increase in the productive sector, the depletion and erosion of natural resources, and the growing social and political pressures aimed at the transformation of the productive system [16], which makes it necessary to establish medium and long-term strategies where activities responds both to internal needs (sales and production), and to the protection and efficient use of natural resources.

Table 2. Electricity and Heat for 2015 Colombia y México

Source of Production	Colombia (GWh)	Mexico (GWh)
Coal	8180	33808
Oil	392	31577
Gas	13350	186251
Biofuels	2204	1760
Waste	0	28
Nuclear	0	11577
Hydro	44833	30815
Geothermal	0	6331
Solar PV	0	246
Solar Thermal	0	0
Wind	58	8745
Tide	0	0
Other sources	0	0
Total production	69017	311138

Source: (IEA, 2018)

Table 3. CO2 emissions, selected countries (MtCO2)

Country	CO2 emissions (MtCO2)
China	9.0 thousand
United States	5.0 thousand
Germany	729.8
Canada	549.2
Brazil	450.8
México	442.3
Italy	330.8
Spain	247.0
Argentina	191.4
Chile	81.7
Colombia	72.3

Source: (IEA, 2018)

Regarding the process of sustainable production and eco-innovation, there are difficulties in articulating the different economic agents in both countries. The companies undertake sustainable strategies under the premise of entering international markets, seeking financial benefits and acting under the order of a public policy, which also results in environmental responsibility activities. In Mexico, the limited development of the same strategies responds to the low assimilation of a sustainable culture. In the private initiative, sufficient efforts have been made to modify its structure towards sustainable production, but these have not resulted in eco-innovations [45]. Publications related to eco-innovation are very few, there are still no case studies presenting innovations of this type, this is not yet common and the benefits that could be generated, from the same companies, are little known.

In this context, the transition to sustainable practices at the company level requires a change of paradigm, stop visualizing sustainability in a single dimension, the environmental one, in order to understand it as an opportunity to innovate the business model through the implementation of processes that generate a greater added value and reduce costs by increasing efficiency and the use of resources. This means a challenge for the design of the strategies of the company, its administration, governance structure, finances and operations.

Both, Colombia and Mexico, have promoted public policies that contribute to the implementation of a sustainable production and consumption from the industries; however, the lack of financing for sustainability, the little environmental education that allows a change in the consumer culture and the low innovative development of the countries, affect the limited processes of articulation between the different economic actors to reach the productive indicators of the SDGs.

It can be concluded that, although the issue has been approached from different levels, perspectives and interests, eco-innovation as part of the operation of the company is still far from being common, thus evidenced the need to continue contributing to research, not only with the purpose of increasing the understanding of the process but with the objective of providing instruments that allow the company to make innovation part of it.

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