Energy Strategy Reviews 43 (2022) 100903

Contents lists available at ScienceDirect

Energy Strategy Reviews

journal homepage: www.elsevier.com/locate/esr

Barriers to renewable energy expansion: Ecuador as a case study

Antonio Barragán-Escandón, PhD [a,*], Darwin Jara-Nieves [b], Israel Romero-Fajardo [b], Esteban F. Zalamea-Leon, PhD [c], Xavier Serrano-Guerrero, PhD [a]

[a] *Grupo de Investigación en Energía, Universidad Politécnica Salesiana, Calle Vieja 12-30 and Elia Liut, Cuenca, Ecuador*
[b] *Universidad Politécnica Salesiana, Cuenca, Ecuador*
[c] *Facultad de Arquitectura y Urbanismo, Universidad de Cuenca, Cuenca, Ecuador*

ARTICLE INFO

Keywords:
Technological innovation systems
Resource mobilization barriers
Ecuador

ABSTRACT

The growth in electricity consumption and the resulting pollution suggests the need to incorporate clean energy sources. Currently, technological advancement is affected by a series of barriers that prevent the adoption of wind energy and solar photovoltaic energy. This research identifies the main barriers that affect these two technologies in the Ecuadorian context. A triangulation approach is applied through a literature review and a structured survey of expert professionals. The homogeneity in the responses affirms that the lack of an energy policy, regulations, inadequate financing, fuel subsidies, and investor uncertainty are useful factors that must be taken into account by various stakeholders to search for mitigating mechanisms that make new projects feasible. Although several studies have been conducted to identify barriers in other contexts, the characterization of barriers has been shown to depend on the conditions of the study environment.

1. Introduction

The implications of environmental deterioration, including the effects of global warming, demand that the energy supply be modified. Globally, fossil fuels constitute the main source of electricity; therefore, electricity consumption contributes greatly to the emission of greenhouse gases (GHGs) [1]. Given the enormous pressure that electricity production places on the environment, proposals that promote sustainability and diversification should be considered. Current technology enables a high proportion of electricity production to be accomplished through the use of renewable resources. However, the applicability of various possibilities depends on local characteristics, such as the availability of resources, costs, policies, and community acceptance.

Solar photovoltaic (PV) energy, wind energy (WE), and other renewable energy (RE) sources are resources that can supply a substantial portion of the global energy demand. However, aspects related to operation, maintenance, and the lack of empathy towards environmental events prevent social acceptance and therefore timely implementation. On the other hand, the intermittency of renewable sources requires them to coexist with conventional energy technologies. In this sense, promoting RE will not eliminate generation based on fossil resources in the short term but will reduce dependence on fossil resources. The Institute for Energy Diversification and Savings of Spain (Instituto para la Diversificación y Ahorro de la Energía de España [2]; established 11 sectors and 22 RE systems; however, some are not in a commercial condition or widely available. Large-scale hydroelectric plants produce negative impacts on ecosystems in both their construction and their operation [3,4]. On the other hand, solar PV energy and WE are becoming more common in the electricity market and currently constitute the fastest-growing energy sources in the world [5]. Nevertheless, appropriate dissemination in all countries is necessary to achieve maximum use.

Energy policies in Ecuador emphasize the need to diversify energy sources [6]. For this reason, substantive mechanisms have been implemented to introduce new technologies to produce electricity. Despite the proposed initiatives, the adoption of WE and PV energy is stagnant compared to that of traditional technologies (hydroelectric and thermal plants) [6,7].

The definition of barriers that affect the diffusion of technologies has its roots in the theories of technological innovation, national innovation systems, and sociotechnical regimes. These theories propose that the definition of the factors of development and diffusion of new technologies can be defined by consulting the actors in a particular sector. Several obstacles of a regulatory, political, environmental, social, or

* Corresponding author.
E-mail addresses: ebarragan@ups.edu.ec (A. Barragán-Escandón), djara@est.ups.edu.ec (D. Jara-Nieves), iromerof@est.ups.edu.ec (I. Romero-Fajardo), esteban.zalamea@ucuenca.edu.ec (E.F. Zalamea-Leon), jserranog@ups.edu.ec (X. Serrano-Guerrero).

https://doi.org/10.1016/j.esr.2022.100903
Received 1 March 2021; Received in revised form 25 May 2022; Accepted 4 July 2022
Available online 9 August 2022

technological nature must be identified, but depending on the country or region where they are analysed, they have different importance. Once these obstacles are identified, specific policy recommendations can be made to target those that are considered most important by the stakeholders.

Eleftheriadis & Anagnostopoulou [1] and Zhang et al. [8] propose the identification of barriers by applying a questionnaire in which stakeholders from various entities participate: private companies, the government, financial institutions, scientists, and NGOs. In this manner, the different points of view will provide a basis for understanding the conditions that affect or promote the development of the analysed sector.

This work identifies barriers that prevent the promotion of WE and PV energy, since knowledge of these barriers will facilitate the promotion of actions supporting the inclusion of energy alternatives in an environment dominated by thermal power plants and large hydroelectric plants. By identifying the obstacles preventing the expansion of new technologies, a more robust electricity sector composed of both conventional technologies and RE can be promoted.

2. Ecuadorian energy context

The Republic of Ecuador is located on the shores of the Pacific Ocean. The country covers a territory of 283,561 km^2 and is located between Colombia and Peru. According to its climate and geography, Ecuador is divided into the Coast, Mountain region, Amazon region, and Insular region. As the country is located on the equator, its conditions are favourable for RE implementation in the field of electricity generation [6]. Crossed by the Andes mountain range, the country has both mountainous conditions and coastal regions. Ecuador has a particular geography and two seasons: rainy and dry. In addition, there is a wide variety of microclimates, which make characterization of the country difficult. From December to May, the rainy season, which is characterized by a contradictorily warmer climate due to the El Niño current in the Pacific Ocean, predominates. From June to November, there are low temperatures and dry conditions. Given the variety of climates and regions, various resources can be exploited as energy sources.

In 2017, the total energy demand in Ecuador was 105 MBOE[1], and the total primary production in the same year was 222 MBOE [9]. Of the total primary demand, 87% was for oil, 5% was for natural gas, and 8% was for RE (hydropower, firewood, cane products, WE, and PV). Dependence on fossil fuels has been maintained for over 40 years [10]. In 2017, diesel, gasoline, electricity, and liquefied petroleum gas represented 32%, 30%, 17%, and 9% of the total energy consumed in the country, respectively [9]. In 2019, the power production was 26,408 GWh, of which 89.63% was generated by hydroelectric energy, while thermal plants produced 10.05%. Wind, PV, biomass, and biogas energy contributed a total of approximately 1.32%. Table 1 shows the installed power capability of the various technologies. Nonconventional energy resources such as biomass, wind, and PV have a limited contribution compared to traditional energy sources.

Fuel consumption (diesel and fuel oil) for power generation has been reduced, which provides the opportunity for participation by large hydroelectric plants with a slight contribution from nonconventional renewable technologies such as WE and PV energy. Diesel consumption decreased by 93.5 million gallons in 2018, which is approximately 45% of the level in 2009. In the same period, fuel oil consumption decreased by 39 million gallons, and residual fuel oil decreased by 10.34 million gallons, which represent 17.33% and 26.56%, respectively, of 2009 levels [12]. Large hydroelectric dams are the power plants providing the main contribution to the Ecuadorian electricity sector, which has resulted in a vast amount of public spending in addition to the environmental impact [14]. This infrastructure does affect the environment,

Table 1
Installed power by type of source in Ecuador. Source: [11–13].

Nominal Power in Electric Power Generation		MW	%
Renewable	Large hydroelectric[2] > 50 MW	4462.39	51.48
	Small hydroelectric ≤50 MW	611.26	7.05
	Biomass	144.30	1.66
	PV	27.63	0.32
	EE	21.15	0.24
	Biogas	7.26	0.08
Renewable Total		5273.99	60.84
Nonrenewable	Thermal MCI	2010.92	23.20
	Thermal turbogas	921.85	10.63
	Thermal turbovapour	461.87	5.33
Nonrenewable Total		3394.63	39.16
General Total		8668.62	100

[a] Although a large hydroelectric plant uses a renewable resource, it is not considered a renewable technology due to the environmental impact it causes in the construction, operation, and removal of the facility.

which explains why the consideration of these plants as clean technology is a subject of debate [15]. In the Ecuadorian case, the use of installed power is growing, with special attention to large power plants, as exemplified by the Coca Codo Sinclair project, with 1500 MW [10]. Projects currently at risk of erosion that affect feed flows [16] expose the fragility of a poorly diversified system.

In Ecuador, hydroelectric plants with a maximum power capacity of 50 MW are considered RE plants [6,7,10]. These systems represent an installed power of 7.05% [13]. Biomass is ranked second, with 1.66%, and PV energy and WE contribute smaller amounts, at 0.31% and 0.24%, respectively. Biogas represents 0.08% of the power generated. While the advantages of nonconventional RE may be notable, their contribution to the country's electricity generation is small. This marginal contribution is attributed to barriers that need to be identified as a precondition to the establishment of policies that increase the adoption of these technologies.

2.1. PV potential in Ecuador

The global radiation in Ecuador varies between 2.9 kWh/m^2 day and 6.3 kWh/m^2 day [17]. For PV generation, at least 3.8 kWh/m^2 day is recommended; the insolation in approximately 75% of the Ecuadorian territory exceeds this value [18]. This potential for electricity production was estimated at 312 GW or 283 MBOE per year, which is comparable to 15 times the national potential for hydropower [19]. Despite this substantial solar potential in Ecuador, PV use remains marginal. The latest report from the Agency of Electricity Regulation and Control (Agencia de Regulación y Control de Electricidad, ARCONEL) indicates that the current PV energy capacity in Ecuador is 27.63 MW [11]. This number represents approximately 0.32% of the effective power produced by renewable and nonrenewable sources. The Ecuadorian solar market has been developed in rural areas to supply electricity to isolated areas [19]. Approximately 5000 PV systems have been installed, mainly in the Amazon region; they provide 0.65 GWh/year [19]. In the case of the country's PV energy plants, the capacity ranges between 0.37 MW and 1 MW.

By 2013, a total of 91 PV projects were under development. In 2019, only 10% of the planned power was installed [6]. Optimizing the production and implementation costs of PV energy systems is a determining factor for this technology to contribute significantly to the Ecuadorian energy matrix. Currently, there are expectations for the construction of the PV solar farm "El Aromo", which would provide an estimated power of 200 MW with a CF of 15.9%. In this case, the state seeks private investment for these projects.

[1] million barrels of oil equivalents.

2.2. WE potential in Ecuador

The gross WE potential in Ecuador has been estimated to be 2870 GWh/year [20]. This resource has not been fully utilized. There are three WE plants currently operating, which contribute a total of 21.15 MW. The first WE plant to open was the San Cristóbal plant in 2007, with a nominal power of 2.4 MW and an annual production of 3.20 GWh. The Baltra Wind Farm, generating 2.25 MW, started in 2014, and the Villonaco Wind Farm has been operating since 2013, with an installed capacity of 16.50 MW. These power plants generate 0.24% of the country's electricity. Phases II and III of the Villonaco Wind Farm, with a power capacity of 110 MW and an estimated capacity factor exceeding 40%, are currently under development. In 2018, the Villonaco Wind Farm exhibited a capacity factor (CF) greater than 85% for July and August [21].

A feasible potential of 1518.17 MW has been estimated for the short term. There are studies showing an available power capacity of 900 MW in coastal areas. In addition, at an altitude of 3500 m, wind speeds greater than 7 m/s have been measured [6,20]. Regarding new projects, construction of the Huascachaca wind farm began in 2019; it is expected to be operating by 2022. The project was initially established with 25 wind turbines generating 2 MW of power each, providing a total power capacity of 50 MW with an annual production of 101 GWh [6]. The project has plans for future expansion with a maximum power capacity of 150 MW.

2.3. Regulations to provide incentives for WE and solar PV energy

The United Nations General Assembly adopted the 2030 Agenda for Sustainable Development in September 2015. The member countries committed to meeting the objectives related to energy use, the creation of infrastructure and the maintenance of the city under sustainable development. This commitment seeks to make cities more resilient with respect to climate change, promoting the economy and reducing poverty at the same time [22]. At the United Nations Conference on Housing and Sustainable Urban Development (Habitat III), held in October 2016 in the city of Quito, Ecuador, the need to promote energy efficiency and the use of nonpolluting energy sources was proposed at the urban level [23]. Under these perspectives, the National Government, through the Plan for the Creation of Opportunities 2021–2025 [24], has established several axes associated with the provisions of the 2030 Agenda for Sustainable Development, as well as guidelines specific to the local situation that seek to create employment, promote energy efficiency policies, conserve ecosystems, regulate nonrenewable resources, and reduce GHG emissions. As an alternative to meet these objectives, it seeks to use renewable resources, which, in addition to being clean and not producing pollutants, can reduce dependence on fossil resources and guarantee long-awaited energy sovereignty [7].

From the normative point of view, the use of renewable energy resources is established in the Constitution. Article 15 states that it is up to the state to promote, in the public and private sectors, the use of environmentally clean technologies and nonpolluting and low-impact alternative energies, as well as energy sovereignty. Likewise, the Organic Law of the Electric Power Public Service establishes in Art. 26 that the state will promote the use of nonconventional renewable energies (NCREs) through regulations defined by the regulatory entity. The Electricity Master Plan, in the chapter related to Sustainable Development (Objective 7), describes the necessity of guaranteeing access to affordable, safe, sustainable, and modern energy for all. In addition, an energy supply with quality, opportunity, continuity, and security is stipulated as a requirement, with diversified, efficient, sustainable, and sovereign energy as the axes of productive and social transformation.

The Organic Code of the Environment and its regulations establish the principle of precaution and extended responsibility. In the first case, measures are encouraged to prevent environmental degradation, while the second principle establishes the responsibility of producers, importers or distributors throughout the life cycle of products [25]. Within the National Strategy for Sustainable Production and Consumption, stipulated in the Regulation of the Environmental Code, it is established that the National Environmental Authority (Ministry of Environment, Water and Ecological Transition) will prepare the National Strategy for Sustainable Production and Consumption, which will include the guidelines to encourage sustainable production and consumption habits, among which the promotion of energy efficiency and the use of renewable energies will be contemplated, in accordance with the national energy policy.

In 2002, the Ecuadorian state implemented a feed-in tariff. Through this policy mechanism, the regulator sets preferential prices for the purchase of RE. Preferential prices were initially implemented for technologies that take advantage of solar, wind, biomass, and geothermal resources. Fig. 1 shows the preferential prices of solar PV and wind energy in the various regulations that were promulgated. As a reference, the prices of conventional technologies vary between 3 and 4 cents/kWh.

However, payment conditions for private projects were not established, so investment companies negotiated directly with distributors, which did not provide payment security due to existing economic problems. In 2009, the participation of self-generators in the self-supply of energy was promoted, and any surpluses could be sold. Mini-hydroelectric power plants (mini hydros) with a maximum power capacity of 50 MW were considered RE, which is a distinction implemented to encourage the creation of this type of power plant. The requirements, costs, forms of distribution, and validity of the nonconventional RE connected to the National Interconnected System (NIS) were established. The scope of this resolution also included projects that were not connected to the power grid [7,26]. This regulation established new prices for RE, with the highest preferential price for solar PV energy. In 2016, the preferential prices were repealed, so the interest in executing this type of project declined.

In 2011, a payment priority was implemented for RE. It was expected that interest in private investment would increase as a result. A preferential price was established for 15 years after subscription, with the intention of stimulating project implementation over a shorter period. Therefore, if a RE project took 3 years to start production, the investor lost the tariff time. Thus, it was up to the investor to streamline the generation processes. For approved projects, $800 million in investments with a power capacity of 355 MW was forecast; however, less than 30 MW has been installed to date.

RE generation has remained stagnant since 2013 due to the reduction in private investment. In 2018, the requirements for power grid connections for solar PV microgeneration were established. This process seeks to promote private self-generation by allowing the sale of

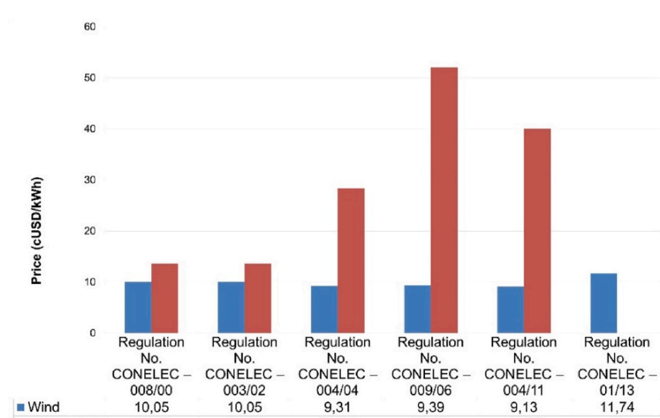

Fig. 1. Preferential prices for nonconventional renewable energy sources (repealed).
Source: [7,26].

surpluses. The regulation establishes a maximum of 100 kW of nominal capacity to allow the connection of low- and medium-voltage users. Regulation 03/18 neither offers incentives nor contemplates the purchase of surpluses if they exceed consumption on an annual balance sheet [27]. Nevertheless, basic technical guidelines were established for PV energy implementation in buildings. For 2021, Regulation No. ARCERNNR 001/21, "Regulatory framework for Distributed Generation for self-supply of regulated electricity consumers", was enacted. This regulation is in force and was approved in 2021 with the aim of establishing the process that distributed generation systems based on renewable sources must comply with. The regulation is applicable to consumers who install systems for their self-supply, systems connected to the network, and distribution companies.

3. Literature review

Several authors have identified the barriers to RE deployment in different contexts. The literature shows that even when similar methodologies have been used to identify these barriers, the results are different. It is necessary to establish the particular drawbacks of the various technologies. To define the barriers, surveys of multiple stakeholders were conducted, which explains why these types of studies were reviewed. This research was based on the identification of barriers proposed by Zhang et al. [8] and Eleftheriadis and Anagnostopoulou [1]. Therefore, to identify similar investigations with similar methodologies, several studies were found with the Scopus and Web of Science (WoS) databases. In the papers presented in Table 2, survey techniques were applied to establish the main barriers in different countries. The table shows the total number of barriers studied as well as the main barriers determined from a certain number of surveys.

Exploring the local situation regarding social, political, institutional, market, economic, environmental, and technological aspects and the way they are perceived in different countries is essential to promoting the expansion of renewable technologies [36]. Even in the same country, different political and economic systems among regions cause these factors to differ [34]. As established by Kumar and Pal [36]; there are general barriers that must be investigated to expand an energy market to include RE and more specific barriers that depend on each technology. In the case of PV technology, Karakaya and Sriwannawit [37] state that although identification must be evaluated in a particular context, for example, with respect to a country or a type of connection to the power grid, barriers commonly constitute four interrelated dimensions:

Table 2
Similar studies in various contexts.

Technology	Location	# Barriers	# Surveys	Main barriers	Source
Solar thermal and PV	China	13	52	High initial and repair costs, Long payback period, Inadequate installation space and service infrastructure, Lack of stakeholder participation, legal and regulatory restrictions.	[8]
Distributed PV energy	Brazil	23	20	Electricity cost, System cost, Energy, Technical parameters, Incentives, Interest rate.	[28]
Solar PV energy and WE	Greece	22	Solar 20 Wind 14	Inadequate financial resources, Power grid capacity, Issuance of permits, Opposition by communities, Stable institutional framework.	[1]
Concentrating solar systems	European Union	10	22	Proven technology, Solar radiation levels, Cost reductions, Technology improvement over time, Dispatch of energy.	[29]
Integrated solar PV systems	Singapore	18	99	Long-term payback period for BIPV, High initial capital cost of BIPV, Low energy conversion efficiency of BIPV systems, Projects awarded to lower-priced tenders, Low electricity prices from conventional sources.	[30]
PVs in cities	China	38	57	Long payback period, High initial cost, Limited space on roofs, Maintenance, Panel efficiency.	[31]
Solar energy	Barbados	11	55	Investment challenges and concerns, Education, Lack of regulations, State of the economy, System costs,	[32]
Concentrating solar systems,	European Union	8	9	High cost of technology, Uncertain and retroactive policies.	[33]
Geothermal, Solar PV, Hydroelectric, Biomass, WE, Other	China	29	39	Capital adequacy, Quality requirement of customers, Creation of technology and R&D capabilities, Competitive parity with conventional energy.	[34]
Hydroelectric, WE, Solar, Biomass, Geothermal	Chile	18	128	Connection restrictions to the power grid and lack of capacity, Long procedures and permitting process, Space and water, Financing, Contracts.	[35]

sociotechnical, administrative, economic, and political. Since the conditions are dynamic over time, another factor that could influence the same study context is the period when the research was conducted. In this sense, technological, market, and regulatory conditions vary; therefore, even when the same barriers are analysed, the priorities can change over time [34].

Zhang et al. [8] established 13 barriers that prevent the development of solar energy (thermal and PV) in Hong Kong, highlighting the high initial and recovery costs, long payback period, inadequate installation space and service infrastructure, lack of stakeholder participation, and legal and regulatory restrictions. In this same region, Mah et al. [31] established 38 barriers to promoting residential PV energy in cities. They conducted surveys of stakeholders involved in the institutional, residential, and commercial sectors. Lam et al. [34] analysed 29 factors critical for RE development in China and found the lack of capital, the need to meet customer quality requirements, technology creation, research and development (R&D) capabilities, and competitive parity with conventional energy to be the decisive factors in this region.

In the case of Greece, barriers to disseminating PV and WE have been discussed. The main common drawbacks are the lack of financial resources, delays in issuing construction permits, and lack of a stable energy policy [1]. Moraes [28] identified factors influencing electricity distribution companies to adopt distributed PV energy technology in Brazil. In this case, the cost of electricity, generation capacity, and PV energy are notable of the 23 barriers analysed. In Chile, among 18 barriers that limit the adoption of solar PV energy, WE, and biomass, hydroelectric, and geothermal energy, the main barriers are connection restrictions, permitting delays, and acquisition of land or water leases.

Barriers in Singapore related to the placement of solar PV energy systems integrated into buildings were identified, and the payback period and investment were determined to be the most concerning issues [30]. In the case of Barbados, the limiting factors for solar energy (thermal and PV) were analysed. It was established that issues related to investment, education, and the lack of policies and regulations are the main challenges [32]. Regarding solar systems in Europe, Kiefer and Del Río [29] identified 22 barriers, of which the maturity of the technology and available resources are noteworthy. In another study on the same technology and in the same regional context, Del Río et al. [38] analysed seven techno-economic barriers, of which the high cost of technology and uncertain and retroactive policies are noteworthy.

In southern Brazil, Garlet et al. [39] identified barriers (technical, economic, social, and political) to PV electricity in distributed generation based on interviews with professionals in the sector. In Chile, 16 barriers were identified and classified into financial, market, integration, and technical barriers [40]. Kar et al. [41] identified barriers to the expansion of solar PV energy in India: connectivity and distribution infrastructure, regulatory and policy developments, capacity utilization, initial capital investment, lack of innovative financing models, and consumer awareness and acceptance. Although these authors mentioned particular barriers for each context, they did not establish a hierarchy according to the importance of these barriers.

This review of the literature establishes that priorities differ among countries and even among regions within countries. Technology and resources play decisive roles, so if clear policies are to be defined, it is essential to identify the specific critical factors that limit the technology at the local level. Although several studies have been conducted to identify barriers in other contexts, the characterization of barriers has been shown to depend on the conditions of the study environment.

4. Methodology

Zhang et al. [8] and Eleftheriadis et al. [1] showed that technological innovation in a particular context can be established through the actors of a particular regime, the networks in which they operate, and local institutions. In this manner, those who know the local situation can provide a very sound basis for understanding the penetration status of a technology. In the same sense, if the barriers that obstruct a technology are known, the specific needs for political intervention can be established, and consequently, specific political recommendations can be made.

To determine the critical factors for promoting RE in Ecuador, related literature was reviewed to identify the background of WE and PV in Ecuador. This review reveals the literature that analyses factors involved in the Ecuadorian technological transition. Information about barriers to promoting WE and PV energy was synthesized. To identify the importance of each barrier, a survey was designed and administered to professionals and stakeholders involved in the public, private, and academic sectors. The last stage analysed the main barriers that were considered priorities by the survey participants. Fig. 2 shows a flowchart of the methodology.

4.1. Identification of barriers to the study environment

The bibliographic review focused on collecting information regarding RE history and current events in Ecuador, specifically for WE and PV energy. Documents such as government plans and reports, academic articles, institutional reports, books, articles from research journals on RE in Ecuador, and studies that were carried out in Latin America (Colombia, Chile, Brazil, and Argentina) were used. The literature related to the energy matrix, electricity generation matrix, and the factors needed to achieve a transition to renewable sources were reviewed. With a base of established barriers, similar studies were analysed. The review also facilitated the definition of the methodology applied in this research. The validity of the barriers proposed for Ecuador was established through a second review. A set of barriers was obtained from the reviewed documents, which focused on countries of the region and barriers considered important for studying the local electricity sector.

Table 3 shows 40 barriers that could affect the implementation of solar PV energy and WE in the Ecuadorian electricity sector. In addition, common barriers identified in the analysed documents were described.

Applying the proposals of Barragán-Escandón et al. [55] and Al Garni et al. [56]; barriers that are cited as constituting less than 15% are discarded. This analysis established 22 matching barriers, which are classified into economic, technical, social, political, or regulatory barriers [37], as shown in Table 4.

4.2. Survey

The applied survey sought participants to rate the 22 previously defined factors on a Likert scale (Table 3). A form was designed and distributed to key stakeholders who are locally involved in the development of PV energy and WE in Ecuador. The survey targeted professionals in the electricity sector, experts linked to academic institutions (professors and researchers), public workers, and private individuals. The surveys were conducted in person and online to encourage the participation of professionals from all over Ecuador. For virtual surveys, the Google Drive platform was employed (Google Forms). The face-to-face survey was directed to teachers and researchers across the country. One hundred professionals from various institutions linked to the Ecuadorian electricity sector, regulatory entities, and private stakeholders were surveyed. The survey included generalities of the research (authors, objectives, a brief introduction, and background).

The number of surveys applied in similar studies varies, as shown in Table 2, so the most appropriate number of participants cannot be established. To carry out the survey, 182 forms were sent. A total of 102 responses were received between the physical and virtual surveys; of the total responses obtained, 100 surveys were validated. To establish the relevance of the different opinions provided by the respondents, the survey was focused on professionals with knowledge in the field of renewable energy. The individuals surveyed are from diverse professional fields: electrical, electronic, mechanical, industrial,

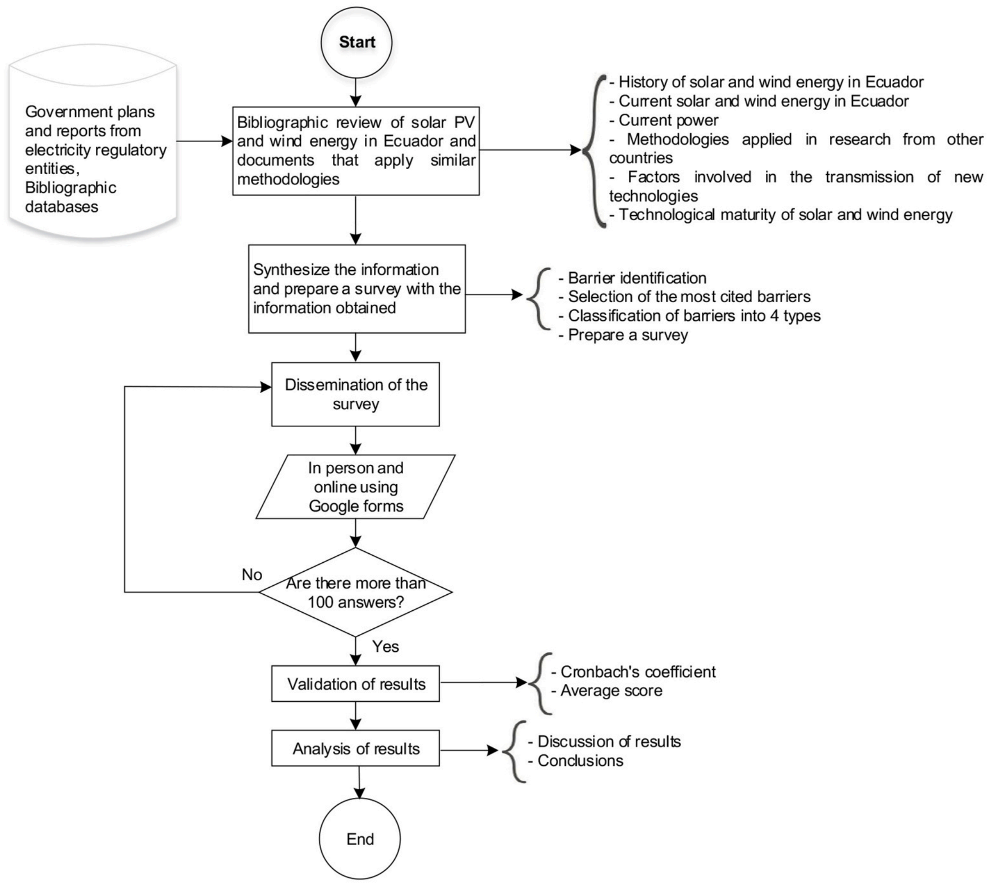

Fig. 2. Flowchart of the proposed methodology.

environmental, automotive, civil, geology, architecture, public management and planning, and engineering. Participants work in various areas and hold various positions. The occupations represented include company managers, researchers, teachers, and representatives of public service companies and private companies. The database obtained from the respondents establishes that 59% of the participants have a master's degree, 23% have a doctorate, those with a diploma and specialization level account for 2%, and finally, 1% and 11% of the respondents hold postdoctoral and third-level degrees, respectively. Of the work activity of the respondents, 39% was considered public activity, 21% was considered private, and 39% was considered academic.

4.3. Data collection

To discriminate professionals who met the characteristics of the research, analysis of the profiles requested in the surveys was performed. Since the search for professionals was carried out, all the profiles were suitable for the study. Characteristics such as experience, training, and professional activity were considered. To establish the order of relevance of the barriers, analysis of the average scores was applied [1,8]. The Likert scale (1–5), where 1 is considered an unimportant barrier and 5 is considered a completely important barrier, was employed. To determine the degree of relevance of the barriers that influence the low inclusion of WE and PV energy in the Ecuadorian electricity market, the average score of each barrier was calculated with Equation (1).

$$(\mathrm{M}) = \sum_{\mathrm{i}}^{\mathrm{j}} \mathrm{P_i} * \mathrm{R_i} \qquad \text{Eq. 1}$$

where.P_i is the sum of score points on the Likert scale (1–5), Ri is the sum of scores for barrier i (Pi) divided by the sum of all scores, and M is the sum of the product of each score point (i … j) and its corresponding Ri for each barrier.

To assess the degree of dispersion of the responses, Cronbach's alpha was used. The Cronbach coefficient is a form of quantitative measurement that determines the stability or consistency of the results obtained by the items of the expression (Equation (2)). In this manner, the degree of reliability of the responses is defined. If the Cronbach coefficient is less than 0.50, it is unacceptable; if it is between 0.50 and 0.60, the instrument is poor; if it is between 0.60 and 0.70, it is questionable; if it is between 0.70 and 0.80, it is acceptable; if it is between 0.80 and 0.90, it is good; and for values near 1, there is a high degree of reliability. Equation (2) establishes how the coefficient is calculated.

$$\boldsymbol{\alpha} = \frac{\boldsymbol{k}}{\boldsymbol{k}-1}\left[1 - \frac{\sum_{i=1}^{k} \boldsymbol{S_i}^2}{\boldsymbol{S_t}^2}\right] \qquad \text{Eq. 2}$$

where.k is the number of items.S_i^2 is the variance of the items.and S_t^2 is the variance of the total observed values.

5. Results

Equation (1) was applied using the survey responses, and then the barriers were ranked in order of importance, as shown in Table 5 and Table 6 for WE and PV energy, respectively. The barriers that influence the expansion of these technologies were arranged so that the barrier with the highest average score is in the first position. A high score indicates that factors with this rating have a higher influence in promoting WE and PV energy technologies. On the chosen Likert scale (1–5), an average score near 4 is considered an important barrier to disseminating these technologies.

Table 3
Barriers identified in various studies.

Source: Authors.

Code		Reviewed Documents																				
References		[21]	[42]	[43]	[44]	[45]	[46]	[47]	[7]	[48]	[49]	[8]	[1]	[50]	[51]	[40]	[52]	[53]	[54]	[35]	[28]	**No. CCoinciding**
Barriers		A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14	A15	A16	A17	A18	A19	A20	
B1	Financing: lack of access to financing for RE projects.	X		X		X	X	X			X	X	X	X		X		X	X	X		13
B2	High upfront investments (investment costs higher than expected).		X			X	X			X		X	X	X			X	X	X	X		11
B3	Problems with access and connection to the power grid and its limited capacity.	X			X			X	X				X		X	X	X	X		X		10
B4	Lack of information or incomplete information: some consumers do not have enough information to study investments in energy conservation and energy efficiency correctly.		X					X		X			X	X	X		X	X	X		X	10
B5	Prices and subsidies (costs associated with renewable energy production are generally higher than those from fossil resources, not considering pollution costs).			X					X				X	X	X	X		X	X	X	X	10
B6	Technology: limited access to efficient technology.	X	X	X	X					X	X		X					X	X			9
B7	Ephemeral, revoked, or unclear regulations.	X	X	X	X								X	X					X	X		8
B8	Local opposition to the development of NCRE projects.	X		X		X				X	X		X						X		X	8
B9	Lack of specialized training for designers, professionals, installers, and maintainers.				X							X	X		X	X			X	X	X	8
B10	The country's hydroelectric potential and the durability of this technology give priority to large-scale hydroelectric energy and displace nonconventional RE.	X								X	X					X		X	X		X	7
B11	Lack of a stable national energy policy.					X		X	X				X				X				X	6
B12	Lack of government support.			X					X			X		X			X		X			6
B13	Energy efficiency and environmental actions are not usually a priority, disregarding the use of clean energy.									X			X		X	X		X			X	6
B14	Lack of institutional consolidation: the promotion of RE responds to an institutional change in the electricity sector and should be considered a change in energy policy.			X					X									X	X	X		5
B15	Delays and withdrawals in construction permits: withdrawal of permits due to lack of environmental studies, feasibility, and final designs.												X			X		X	X	X		5
B16	Energy illiteracy: ignorance or inadequate knowledge about RE technologies that can be offered in Ecuador.				X					X								X			X	4
B17	The capacity factor in WE and solar PV installations compared to conventional generation units is relatively low.	X								X	X						X					4
B18	Lack of sale guarantees in the electricity production sector can be considered a barrier for investors seeking involvement in this new activity.										X	X	X		X							4

(*continued on next page*)

Table 3 (*continued*)

Source: Authors.

Code		Reviewed Documents																				
References		[21]	[42]	[43]	[44]	[45]	[46]	[47]	[7]	[48]	[49]	[8]	[1]	[50]	[51]	[40]	[52]	[53]	[54]	[35]	[28]	**No. CCoinciding**
B19	Low involvement of key stakeholders.		X		X							X										3
B20	Uncertainty in investments by entrepreneurs who can verify potential profits according to the predicted future price of energy.									X			X		X							3
B21	Long payback period.											X	X							X		3
B22	Shortage of renewable resources for electricity generation.											X			X					X		3
B23	Economic: investment costs, energy prices, etc.																	X	X	X		3
B24	Legal and regulatory restrictions.																	X	X		X	3
B25	Need for effective administration.	X	X																			2
B26	Legislation on energy conservation and energy efficiency is usually scattered and still has development potential.		X	X																		2
B27	Difficulty quantifying and measuring the benefits associated with energy efficiency.		X														X					2
B28	Structural problems in installation in existing buildings.											X								X		2
B29	Lack of national manufacturing industry for NCRE.												X			X						2
B30	Inaccessibility to areas with renewable resources.														X	X						2
B31	Lack of social and end-consumer acceptance.																	X	X			2
B32	Difficulty in negotiations in energy purchases.																	X		X		2
B33	Mindset of megaprojects versus small-scale energy projects.																		X		X	2
B34	Idiosyncrasy and scepticism of local stakeholders towards RE.	X																				1
B35	Unfavourable aesthetic considerations for implementing renewable technologies.											X										1
B36	Environmental benefits not recognized by energy authorities.																	X				1
B37	Tendency to privilege the extension of power grids over RE installation.																	X				1
B38	Inability to determine strategic sites with renewable resource.																				X	1
B39	Noise pollution produced by wind turbines.																				X	1
B40	Difficulty implementing nonconventional RE in cities.																	X				1

Table 4
Main barriers in the analysis for the Ecuadorian case Source: Authors.

Type of barrier	Code	Barrier
Economic 	B1	**Financing:** Lack of access to adequate financing for WE and PV projects.
	B2	**Investment cost:** The initial investment cost for WE and PV technology is high, since there are no guarantees from the state.
	B5	**Fuel subsidy:** The low price of fuel facilitates the use of thermal power plants, which weakens the implementation of new technologies, such as WE and PV energy.
	B18	**Lack of guarantees in the sale of energy in the electricity sector:** Investors who wish to get involved in this activity have no guarantees for the sale of energy.
	B20	**Uncertainty from entrepreneurs:** Investors experience legal insecurity that prevents them from having confidence about future energy prices.
	B21	**Long payback period:** As there are no guarantees, the delay in obtaining profits is long.
Technical 	B3	**Problems with permissions to access and connect to the power grid:** Given the locations of the sites where resources are available, connecting to the power grid is difficult, or the regulations for connection are missing.
	B6	**Limited access to efficient technologies for electricity generation:** As new technologies, there is a lack of equipment availability for WE and PV energy technologies at the local level.
	B9	**Lack of specialized training for designers, professionals, installers, and maintainers:** The country still does not have professionals for the correct implementation and expansion of this technology.
	B10	**Hydroelectric potential:** The great potential of the country based on this resource and the durability of its facilities prioritizes large hydroelectric plants and displaces WE and solar PV energy.
	B15	**Delays and withdrawals in construction permits:** Delays in permits for the construction of WE and PV energy farms due to a lack of environmental studies, feasibility, and final designs.
	B17	**Capacity factor (CF):** In WE and PV energy facilities, the CF is relatively low compared to those of conventional generation units, which attracts minimal interest in generating electricity from renewable resources.
	B22	**Shortage of renewable resources necessary for electricity generation:** The real potential of the resources is unknown due to the lack of specific studies.
Social 	B4	**Lack of information or incomplete information:** Consumers and investors do not have the information for these technologies and their application.
	B8	**Local opposition to the development of nonconventional RE projects (WE and PV energy):** This opposition is due to a lack of knowledge about the advantages of these new technologies.
	B13	**Environmental awareness:** Energy efficiency actions and concerns about environmental pollution are not usually priority actions.
	B16	**Energy illiteracy:** This illiteracy is due to ignorance or inadequate knowledge about the potential and benefits that WE and PV energy can offer in Ecuador.
	B19	**Low involvement of key stakeholders:** The lack of RE projects that benefit the electricity sector is caused by the lack of negotiations between the public sector and private sector.
Policies and Regulations 	B7	**Ephemeral, revoked, or unclear regulations for WE and PV:** Lack of regulations that encourage the use of these RE sources.
	B11	**Lack of a stable national energy efficiency policy:** The energy policy must include tariff and tax measures, preferential prices to promote the use of RE, and regulations mandating compliance.
	B12	**Lack of government support:** The government does not consider the expansion of these new technologies a priority, which leads to a lack of interest in project proposals.
	B14	**Lack of institutional consolidation:** Lack of institutes or centres of study focused on RE and energy efficiency.

Table 5
Main barriers that influence the expansion of WE in Ecuador. Source: Authors.

Type of barrier[a]	Code	Unimportant		Slightly Important		Neutral		Somewhat Important		Completely Important		Sum	(M)	Rank
		1		2		3		4		5				
		P_i	R_i	P_i	R_i	P_i	R_i	P_i	R_i	P_i	R_i			
PB	B11	1	0.01	4	0.04	6	0.06	28	0.28	61	0.61	100	4.44	1
EB	B1	2	0.02	4	0.04	4	0.04	31	0.31	59	0.59	100	4.41	2
PB	B7	1	0.01	4	0.04	7	0.07	33	0.33	55	0.55	100	4.37	3
EB	B20	2	0.02	8	0.08	12	0.12	26	0.27	50	0.51	98	4.16	4
EB	B5	4	0.04	8	0.08	11	0.11	23	0.23	53	0.54	99	4.14	5
SB	B13	0	0.00	8	0.08	17	0.17	36	0.36	38	0.38	99	4.05	6
EB	B18	4	0.04	10	0.10	10	0.10	31	0.31	45	0.45	100	4.03	7
PB	B12	2	0.02	8	0.08	17	0.17	31	0.31	42	0.42	100	4.03	8
TB	B10	2	0.02	10	0.10	12	0.12	35	0.35	41	0.41	100	4.03	9
TB	B3	3	0.03	10	0.10	12	0.12	35	0.35	40	0.40	100	3.99	10
EB	B21	4	0.04	5	0.05	16	0.16	37	0.37	37	0.37	99	3.99	11
PB	B14	5	0.05	8	0.08	16	0.16	33	0.33	38	0.38	100	3.91	12
EB	B2	5	0.05	7	0.07	19	0.19	32	0.32	37	0.37	100	3.89	13
SB	B19	4	0.04	9	0.09	15	0.15	39	0.39	32	0.32	99	3.87	14
SB	B4	7	0.07	4	0.04	19	0.19	34	0.34	35	0.35	99	3.87	15
SB	B16	4	0.04	7	0.07	20	0.20	37	0.37	32	0.32	100	3.86	16
TB	B15	5	0.05	12	0.12	14	0.14	33	0.33	35	0.35	99	3.82	17
TB	B9	5	0.05	8	0.08	18	0.18	36	0.37	31	0.32	98	3.82	18
TB	B6	8	0.08	12	0.12	18	0.18	23	0.23	39	0.39	100	3.73	19
TB	B22	5	0.05	12	0.12	24	0.24	30	0.30	29	0.29	100	3.66	20
TB	B17	7	0.07	15	0.15	21	0.21	35	0.35	22	0.22	100	3.50	21
SB	B8	11	0.11	14	0.14	20	0.20	31	0.31	24	0.24	100	3.43	22

[a] EB, economic barriers; PB, political barriers; SB, social barriers; TB, technical barriers.

Table 6
Main barriers that influence the expansion of PV energy in Ecuador. Source: Authors.

Type of barrier[a]	Code	Unimportant		Slightly Important		Neutral		Somewhat Important		Completely Important		Sum	(M)	Rank
		1		2		3		4		5				
		P_i	R_i	P_i	R_i	P_i	R_i	P_i	R_i	P_i	R_i			
PB	B11	1	0.01	5	0.05	7	0.07	27	0.27	60	0.60	100	4.40	1
PB	B7	1	0.01	4	0.04	7	0.07	35	0.35	52	0.53	99	4.34	2
EB	B1	2	0.02	6	0.06	5	0.05	30	0.30	56	0.57	99	4.33	3
EB	B5	3	0.03	6	0.06	10	0.10	25	0.26	54	0.55	98	4.23	4
EB	B20	2	0.02	8	0.08	11	0.11	26	0.27	51	0.52	98	4.18	5
TB	B10	2	0.02	10	0.10	10	0.10	35	0.35	42	0.42	99	4.06	6
SB	B13	0	0.00	8	0.08	17	0.17	36	0.37	37	0.38	98	4.04	7
PB	B12	2	0.02	8	0.08	17	0.17	31	0.31	42	0.42	100	4.03	8
TB	B3	3	0.03	9	0.09	12	0.12	34	0.35	40	0.41	98	4.01	9
EB	B18	4	0.04	11	0.11	9	0.09	33	0.34	41	0.42	98	3.98	10
EB	B21	4	0.04	6	0.06	17	0.17	35	0.35	38	0.38	100	3.97	11
SB	B16	3	0.03	7	0.07	19	0.19	38	0.39	31	0.32	98	3.89	12
PB	B14	5	0.05	8	0.08	16	0.16	35	0.35	35	0.35	99	3.88	13
SB	B19	4	0.04	8	0.08	18	0.18	37	0.37	33	0.33	100	3.87	14
EB	B2	5	0.05	5	0.05	20	0.20	36	0.37	32	0.33	98	3.87	15
SB	B4	7	0.07	4	0.04	20	0.20	34	0.34	35	0.35	100	3.86	16
TB	B15	6	0.06	11	0.11	14	0.14	33	0.33	35	0.35	99	3.81	17
TB	B9	5	0.05	12	0.12	16	0.16	35	0.36	29	0.30	97	3.73	18
TB	B6	8	0.08	11	0.11	17	0.17	29	0.29	35	0.35	100	3.72	19
TB	B22	5	0.05	14	0.14	25	0.25	32	0.32	23	0.23	99	3.55	20
TB	B17	7	0.07	15	0.15	18	0.18	35	0.35	24	0.24	99	3.55	21
SB	B8	11	0.11	14	0.14	21	0.21	31	0.31	23	0.23	100	3.41	22

[a] EB, economic barriers; PB, political barriers; SB, social barriers; TB, technical barriers.

Cronbach's alpha (α) values applied to the items related to WE and PV energy were 0.87 and 0.86, respectively, which establishes that the responses of the participants were homogeneous. The degree of homogeneity according to the segmentation by sector was $\alpha = 0.95$ for the public sector, $\alpha = 0.92$ for the private sector, and $\alpha = 0.89$ for the academic sector. However, the results obtained regarding the relative importance of each barrier differ among sectors due to the specific perception of each involved sector. Table 7 shows the values obtained for α. However, note that the results of the surveys are reliable.

6. Discussion

New clean technologies typically developed in first-world countries must be transferred to developing regions to promote economic growth. Zhao et al. [57] showed that in China, this strategy is valid for achieving sustainable development with important political implications, which can be extended to developing countries such as the Ecuadorian case.

The political decision is essential, and the technologies are initially expensive in comparison to the traditional technologies; therefore, for the diffusion and proliferation of RE, an initial stage is required that promotes their promotion through subsidies or credits until the industry develops on its own. The cost per kW is influenced by the diffusion and maturity of the technology, so the highest energy costs are usually for small systems. However, there are technologies, such as PV, that could be expanded throughout the city in domestic systems. Since there is no expectation that the energy in the city will be produced in large power plants, an economy of scale related to large production centres is not expected; in fact, this is an advantage of multi-MW projects [58]. In this case, it is understood that an economy of scale can be achieved with the possibility of expanding the manufacturing and assembly of renewable energy devices, which in the long run will cause a decrease in the cost of the equipment [59], promoting its use and economic convenience.

Table 7
Indicators obtained by calculating Cronbach's coefficient. Source: Authors.

Criterion	Cronbach's Coefficient (α)			
	All Participants	Public Sector	Private Sector	Academic
General Survey	**0.93**	**0.95**	**0.92**	**0.89**
WE	**0.87**	**0.91**	**0.83**	**0.79**
PV	**0.86**	**0.89**	**0.85**	**0.81**

To put the above into practice, it is necessary to establish strategies that aim at a sustainable energy system based on indigenous resources [60]. In this sense, Haberl [61] states that the knowledge of the analyses derived from studies of energy flows is one of the first steps to increase the efficiency of the resources used, promoting that the countries, and in particular the cities, stop being receptors and achieve a certain energy independence and democratization [62–64]. Similarly, Carlisle et al. [65] suggest that planners should determine energy uses and then propose milestones to promote autonomous communities.

Zhao et al. [57] consider that emerging countries do not define how to achieve sustainable development (that is, reconcile economic growth, environmental protection, and social development), but the gradual adoption of these mechanisms is a basic strategy for the transformation and development of the local economy in line with global objectives. A "green" economy must lean towards projects such as green technology, clean energy, and environmental protection. In fact, there is evidence that environmental regulations positively affect green finance through short- or long-term external financing [66]. Regulations associated with compliance with sustainability principles are necessary in developing countries since they force companies to assume environmental responsibilities [66].

What is interesting about the results obtained is that levels of homogeneity of responses of both academics and stakeholders from the public and private sectors can be considered acceptable ($\alpha > 0.80$). Although there are different values if each group of respondents is taken individually, it is appropriate to conclude that there is a convergence. This homogeneity in the responses makes it possible to affirm that for both PW and WE, the lack of an energy policy (B11), lack of regulations (B7), inadequate financing (B1), fuel subsidies (B5), and investor uncertainty (B20) are useful barriers that must be taken into account by the various actors to search for mitigating mechanisms that make new projects feasible.

The values ordered by the average scores for PV energy indicate that the factors with the greatest influence on the low level of implementation of this technology are political. The lack of a stable national energy policy (B11) and regulations that encourage the use of these technologies (B7) are ranked first and second. From an economic point of view, the inability to access adequate financing (B1) and the existing subsidy for fossil fuels (B5) are the economic barriers with the highest scores; they occupy the third and fourth positions, respectively, for this technology. It is also established that the low densities of PV energy projects are due to investor uncertainty about future energy prices (B20), as this barrier is the fifth most influential for PV energy.

For the WE case study, the factors with the greatest influence are political and economic. The lack of a stable national energy policy (B11) and the difficulty in accessing adequate financing (B1) are in first place and second place, respectively, followed by a lack of regulations that encourage the use of this technology (B7). Investor uncertainty about future energy prices (B20) occupies fourth place. Of the five factors mentioned, fuel subsidies (B5) have the smallest effect on the implementation of WE plants.

The barrier (B11) exhibited the highest score for WE, similar to the case with PV energy, which shows that both technologies need policies and regulations that help to promote them. These results coincide with the analysis by OLADE [67]; which suggests that in most South American countries, an insufficient number of energy efficiency policies (B11) focused on RE are in place. It is evident that these technologies require regulations (B7) and long-term objectives to provide these new technologies with an adequate maturation time. In the Ecuadorian case, stable regulations are needed to guarantee payment for electricity generation projects. International agencies are seeking speculative markets, and their funds go to countries such as Brazil and Chile with better regulatory frameworks or areas of Africa, which rules out other countries in the region, including Ecuador.

The Director of the Ecuadorian Association of RE and Energy Efficiency indicated that in previous years, there were better conditions, such as preferential prices; however, administrative barriers made it difficult to effectively implement these technologies [68]. Several projects, mostly based on biomass or PV, continue to operate under preferential rates. However, since 2013, these prices have been phased out for both WE and PV. Mena [69] considers not only that public policy should guide decisions on RE integration but also that private capital is needed to achieve a successful energy transition. The promotion of hydroelectric plants was largely financed with public funds, which constituted an aggressive subsidy for this technology that can cause substantial environmental impacts. Allocating similar levels of funding to other sources would be a logical approach for achieving more reliable power grids that would minimize the risk of unexpected natural events such as a lack of rainfall that reduce individual types of resources. Furthermore, distributed generation not only contributes to RE self-sufficiency but also promotes local employment in developing countries [70].

Norms are needed to establish rates that support a safe investment for 15–20 years and account for generation costs and adequate capitalization time [68]. An energy policy must include tariff and tax measures, preferential prices, and mandatory technical regulations to promote the use of alternative renewable technologies. The financing (B1) of a project in the field of electricity generation is essential. In some cases, excellent projects or technology initiatives have been stagnant due to a lack of funding. In other words, a regulatory framework that involves financing helps investors have greater confidence.

Regarding WE, barrier (B1) is in second position, while it is in third position for PV energy. The high cost of wind turbines compared to PVs makes the necessary financing higher for WE, which affects the adoption of this technology. The investment required for PV energy can vary depending on the number of panels used, while for a single wind turbine, the required capital is high, and even the transport of this infrastructure is more difficult.

In Ecuador, the real cost of electricity production and distribution is USD 0.09/kWh and is reduced to USD 0.04 USD/kWh after the public subsidy [6]. However, the calculated electricity prices for PV and wind technologies are 0.12 USD/KWh and 0.15 USD/KWh, respectively [71]. Investment and energy costs are decisive factors; if these technologies are not financially attractive to implement, it is very difficult to establish them, especially when considering that REs are small distributed sources [7]. Citizens will assume that it is preferable to pay an electricity tariff instead of paying for their own installations and maintaining them with respect to the energy received from the network. As a consequence, targeted subsidies are needed to allow sales of microgeneration to the grid. Likewise, policies are required to allow technologies such as solar PV to be incorporated into urban infrastructures and buildings as well as in intelligent networks. The very high availability of hydroelectric energy at the country level may continue to condition the implementation of these technologies on a small and even large scale [72].

These factors show that it is necessary to promote guarantees and financial services for medium- and small-sized companies. Distribution companies are required to capture energy generated from RE; however, they prioritize other contracts and their economic costs. The lack of guarantees causes investors to perceive the sector as a risky environment (B20). Currently, there is a regulatory framework (PV microgeneration for self-consumption); nevertheless, the distributors are initially not prepared to accept this type of project given their lack of experience. The uncertain market (B20) is seen as less influential for PV (fifth place) than for WE energy (fourth place) according to the average score scale. This finding is perhaps due to the accessibility of small-scale PV projects that can be installed in homes and connected to the power grid.

Prices and subsidies (B5) form one of the most influential barriers to the successful promotion of nonconventional RE. This factor may be particularly important in the Ecuadorian electricity sector, which makes technologies based on fossil fuels more attractive than renewable technologies. Subsidized fuel has also led to the use of thermal power plants [73], which have the second-highest contribution to electricity generation in the country and have detracted from the implementation of RE plants [11,74,]. In 2007, electricity was also subsidized by the "Dignity Rate" of 4.0 USc/kWh for residential and low-consumption customers [75]. Approximately 2.1 million residential customers benefited from this policy . As a result, polluting sources were subsidized, which rendered micro- and self-generation noncompetitive.

Customers in the industrial sector pay a value closer to the real value ($0.09 USD per kWh) to partially finance the electricity subsidy [74,76]. In Ecuador, it is not considered important to rely on fuels for electricity generation since there is a stable guarantee for sustainable energy; however, it cannot be ruled out that cost is an obstacle for RE [43]. The price of fossil fuels does not include external factors, such as the cost of remediation for environmental pollution, health, and visual pollution. According to the average scores, fuel subsidies affect the two technologies, but the score is slightly higher for PV energy.

Ultimately, high oil prices are critical to the economies of exporting countries; however, such prices conflict with the incentive to promote the use of RE. The Organization of Petroleum Exporting Countries (OPEC) has established that Ecuador has 8300 million barrels of oil in proven reserves. These considerable reserves increase the interest in oil exporting and capital investment. Nevertheless, a large portion of this capital must be invested in the purchase of fuels [74,77]. In this sense, Castro [77] noted the inconsistency of promoting incentives for renewable technologies while strongly subsidising the price of fuels. The operating cost of fuel-based technologies reaches minimum values for which any alternative is unattractive to the population.

Regarding social and technical barriers, factors such as environmental awareness (B13) and hydroelectric potential (B10) have values greater than 4 on the average score scale. This difference is considered unrepresentative compared to the aforementioned barriers. In relation to this criterion, the importance of analysing these factors is recognized since they show a degree of relevance in the implementation of WE and PV energy.

c Lack of environmental awareness (B13) and low societal participation in energy efficiency actions are aggravating the low level of inclusion of WE and PV energy. The low demand for new technologies that help to conserve the environment appears to be due to minimal environmental culture. The lack of environmental empathy and the strong support for subsidies have made political attempts to withdraw subsidies impossible, even by environmental political leaders. Inadequate knowledge of the new forms of electricity generation becomes an obstacle to the participation of new technologies. Based on these criteria, it is inferred that the population perceives new technologies as luxuries that are only available to developed countries, which discourages their implementation. Disregarding the environmental impact produced by thermal power plants or omitting the risk of relying on hydroelectric power limits the introduction of new options [7,43,78].

With reference to hydroelectric potential (B10), Ecuador possesses a considerable number of water reserves. Most of these reserves are concentrated in the Amazon region, which is why resources have been focused on the construction of large-scale projects. The literature indicates that the hydroelectric potential and durability of hydroelectric facilities are not direct barriers to implementing new technologies. While the hydroelectric potential has not been considered a barrier, the centralized approach to the construction of large hydroelectric plants is considered a barrier. The analysis concludes that hydroelectric potential (B10) has a greater influence on the low implementation of PV technology than on the implementation of WE plants.

Another technical barrier that specifically affects PV energy is the problem of connecting to the power grid (B3). This barrier is considered to be influenced by the lack of a regulation that facilitates the connection points and the lack of approval for the environmental studies required for construction. During water shortages, the flow of rivers declines due to reduced cloud formation, and as a result, a low cloud density increases the solar potential, which illustrates a complementarity between water and solar sources.

The least influential factor hindering the implementation of WE and PV technology is local opposition to project development (B8). Similarly, the scarcity of adequate resources (B22) and capacity factor (B17) are established as the technical barriers that have the least influence on the low implementation of these technologies.

It is noted that in each country analysed, there are different barriers. However, another variable that can make comparisons difficult is the time the study was carried out, since the prices on the markets, the maturity of the technology, or the international interest in adopting policies that promote energy sustainability may differ. In the cases studied, it is noted that the lack of clear policies (B11) and regulations (B7) represent an obstacle in China, Brazil, and Chile [8,28,35]. Likewise, inadequate financing (B7) is common in Chile [28]. In the case of China and Greece, as in the present research, among the main barriers is the uncertainty of investments (B20) [1,8]. In the Ecuadorian case, the fuel subsidy for energy production [28,32] is reported by the respondents as an aggravating factor that prevents the penetration of renewables. Although there have been attempts to reduce or remove these subsidies, an important sector of Ecuadorian society opposes this elimination, despite the fact that the subsidies exceed 1900 million dollars.

7. Conclusions and policy implications

Since society inevitably causes changes in the environment, it is necessary to anticipate the adverse effects that could be caused. There are several possibilities and technologies that must be considered based on the evaluation of local resources and needs. As a first step, several available renewable resources need to be evaluated, and in-depth knowledge of the flows of energy carriers is necessary. On the other hand, financing mechanisms must be identified, adequate regulations must be created, and the commitment to and acceptability of RE by citizens must be encouraged, in addition to establishing a solid municipal structure that includes energy as one of its development axes.

The research carried out determined that while there are several complex factors in the development and promotion of WE and PV energy technologies, some factors have a greater influence on the expansion of new projects via renewable technologies. From the bibliographic review, 40 blocking barriers were established for the promotion of RD, of which 22 are the most common in the Latin American context. To identify the blocking mechanisms that hinder the implementation of wind energy in Ecuador, a methodology based on consulting experts about the national situation was used. The validation of the results applying Cronbach's alpha establishes that the perception is homogeneous in the different interest groups consulted. The five barriers that WE and PV energy face to increase their participation in the power supply to the electrical system have been established: i) the lack of an energy policy, ii) lack of regulations, iii) inadequate financing, iv) fuel subsidies, and v) investor uncertainty, are useful barriers that must be taken into account by the various actors to search for mitigating mechanisms that make new projects feasible.

The momentum of these technologies is stagnant; thus, these technologies must be more effectively promoted for a successful development stage to begin. Although there are laws that indicate the need to promote the use of unconventional energy sources, in practice, there are no clear mechanisms to accelerate the construction and subsequent initiation of processes. Ecuador has transformed from a market monopoly model to a model with generation, transmission, and distribution in separate companies; however, it continues to feature a majority participation. Moreover, any initiative must be within the National Electrification Plans, and if a project falls outside of these plans, the processes to promote new projects discourage private investment, for example. In this sense, the state still favours traditional technologies. Hence, it is necessary for the state to promote private initiatives in a way that minimizes obstacles for large consumers or local promoters to introduce projects. The government could thus focus resources on other sectors while promoting a robust, integrated, and more diversified electricity sector.

Inadequate financing influences the ability of private companies to obtain local loans with competitive interest rates. In fact, the lack of knowledge and experience prevents PV or WE projects from being analysed as profitable businesses. As a result, these projects are considered risky and highly capital intensive. The regulated tariff was in force for several years, and, as noted, it did not provide the desired results. It is clear then that even when WE and PV energy provided obvious price advantages over traditional sources of electricity, there was a lack of interest in the country to promote this type of project. In this sense, credit agencies must consider costs, maturity of technologies, and the local context so that financial indicators provide knowledge of the profitability and recovery periods of RE projects.

Subsidies associated with energy prevent the entry of renewable energies into the energy mix. Hence, subsidies should not only be targeted to sectors that need them to avoid inefficiency in their use; to avoid social opposition, it is necessary to empower citizens, since the increase in demand for energy will cause the amounts allocated to energy to increase over time. Undoubtedly, for Ecuador, the decisions made are political and require dialogue among the various sectors of society. The inclusion of renewable energy certificates and renewable energy standards when applied in a developing context could increase investment in renewable energy to a certain extent, but it would be important to control the price of green labels that are too expensive, which could imply an adverse effect [79].

To avoid legal uncertainty, it is necessary that medium- and long-term planning not change significantly, as such change would raise uncertainty in the private sector and prevent domestic and foreign capital from promoting the construction of PV and WE projects. This effect may occur because the main promoter of projects continues to be the state, which prevents the participation of other agents. From the perspective of Ecuadorian society, there is an inadequate or nonexistent perception among the inhabitants of nonconventional RE. Associated with a lack of environmental awareness, it is argued that there is little sustainable development culture in the population, which impairs efforts to press political entities to act on this issue. The lack of a sustainable development culture influences the low acceptance of new renewable technologies that could be part of a system based on hydroelectric and thermal power plants. Another aspect that has not been considered in this research corresponds to city population and industrial aspects [80]; thus, further research should take into account the characteristics of different cities in Ecuador.

From a perspective focused on social barriers, promoting self-generation in the population is considered relevant. Self-generation must be seen and prioritized as a means of energy savings. Communication, advertising, and training campaigns are necessary to raise awareness among the population of environmental issues and WE. While self-generation does not cause noticeable changes in the energy matrix in the short term, its promotion generates changes in the environmental awareness of the population, which induces a conscious use of energy and promotes the use of renewable technologies in residential and commercial buildings. The population does not know or consider other alternatives that, in addition to being clean, could promote employment and reduce fossil resource consumption.

Author contributions

Barragan-Escandon E.A.: Conceptualization, Methodology, Validation, Supervision, Formal Analysis, Investigation, Data Curation, Writing Original Draft, Visualization, Founding Acquisition; **Esteban F. Zalamea-Leon:** Validation, Investigation, Resources, Data Curation, Writing - Review & Editing, Visualization, Project Administration, Founding Acquisition; **Jara-Nieves D. and Israel Romero-Fajardo :** Methodology, Formal Analysis, Software; **Serrano-Guerrero X.:** Validation, Resources, Writing - Review & Editing, Supervision, Project Administration, Writing - Review & Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgements

This research was supported by Grupo de Investigación en Energía (Energy Research Group), Universidad Politécnica Salesiana (Salesian Polytechnic University) and Universidad de Cuenca (University of Cuenca). It is a component of the research project “Modelado y mediciones de condiciones ambientales interiores e integración de energía solar, para alcanzar el Estándar Net-Zero en Edificaciones FAUC (Modeling and measurements of indoor environmental conditions and integration of solar energy, to achieve the Net-Zero Standard in FAUC Buildings)”.

References

[1] I.M. Eleftheriadis, E.G. Anagnostopoulou, Identifying barriers in the diffusion of renewable energy sources, Energy Pol. 80 (2015) 153–164, https://doi.org/10.1016/j.enpol.2015.01.039.
[2] IDAE, Plan de energias renovables 2011 2020, España, Madrid, 2011.
[3] J. Gosens, F. Hedenus, B.A. Sandén, Faster market growth of wind and PV in late adopters due to global experience build-up, Energy 131 (2017) 267–278, https://doi.org/10.1016/j.energy.2017.05.046.
[4] Z. Lin, J. Qi, Hydro-dam – a nature-based solution or an ecological problem: the fate of the Tonlé Sap Lake, Environ. Res. 158 (2017) 24–32, https://doi.org/10.1016/j.envres.2017.05.016.
[5] IRENA, Global Energy Transformation: the REmap Transition Pathway (Background Report to 2019 Edition, 2019. Abu Dhabi.
[6] M.A. Ponce-Jara, M. Castro, M.R. Pelaez-Samaniego, J.L. Espinoza-Abad, E. Ruiz, Electricity sector in Ecuador: an overview of the 2007–2017 decade, Energy Pol. 113 (2018) 513–522, https://doi.org/10.1016/j.enpol.2017.11.036.
[7] E. Barragán, J.L. Espinoza, Políticas para la promoción de las energías renovables en el Ecuador, in: M.R. Peláez Samaniego, J.L. Espinoza Abad (Eds.), Energías Renovables En El Ecuador. Situación Actual, Tendencias Y Perspectivas, Universidad de Cuenca, Gráficas Hernández,, 2015, https://doi.org/10.1017/CBO9781107415324.004. Cuenca, Ecuador, Ecuador.
[8] X. Zhang, L. Shen, S.Y. Chan, The diffusion of solar energy use in HK: what are the barriers? Energy Pol. 41 (2012) 241–249, https://doi.org/10.1016/j.enpol.2011.10.043.
[9] Mernnr, Balance Energético Nacional 2017. Quito, Ecuador, 2017.
[10] GIZ, Análisis de las oportunidades I+D+i en eficiencia energética y energías renovables en el Ecuador, Un enfoque desde el sector académico, Quito, Ecuador, 2016.
[11] ARCONEL, Balance Nacional de Energía Eléctrica, 2019. Quito, Ecuador.
[12] ARCONEL, Estadísticas anual y multianual del sector eléctrico ecuatoriano, ARCONEL, Quito, Ecuador, 2018.
[13] CENACE, Informe Anual 2018. Quito, Ecuador, 2018.
[14] B. Miranda, Coca Codo Sinclair: los problemas de la multimillonaria represa que China construyó en Ecuador, BBC, 2019.
[15] B. Romero-Anazco, B. Siguenza-Maldonado, A. Barragan-Escandon, X. Serrano-Guerrero, Methodology to evaluate the repowering of small hydroelectric power plants: Case study El Amarillo in Portovelo, Ecuador, in: 2019 IEEE Int. Autumn Meet. Power, Electron. Comput. ROPEC 2019, 2019, pp. 1–6. https://doi.org/10.1109/ROPEC48299.2019.9057097.
[16] A. Paz-Cardona, Ecuador races for emergency infrastructure as river’s collapse threatens dam [WWW Document]. News.Mongabay. URL, https://news.mongabay.com/2020/08/ecuador-races-for-emergency-infrastructure-as-rivers-collapse-threatens-dam/, 2020. accessed 8.8.20.
[17] X. Serrano-Guerrero, D. Alvarez-Lozano, S.F.L. Romero, in: Influence of local climate on the tilt and orientation angles in fixed flat surfaces to maximize the capture of solar irradiation: A case study in Cuenca-Ecuador, IEEE, 2019, pp. 1–6. https://doi.org/10.1109/ROPEC48299.2019.9057102.
[18] D. Vaca-Revelo, J. Lopez-Villada, Mapa solar del Ecuador, Quito, Ecuador, 2019.
[19] J.P. Muñoz-Vizhñay, M.V. Rojas-Moncayo, C.R. Barreto-Calle, Incentive pertaining to energy the generation distributed in Ecuador, Ingenius. Rev. Cienc. y Tecnol. (2018) 60–68.
[20] Meer, Atlas eólico del Ecuador confines de generación eléctrica, Quito, Ecuador, 2013.
[21] E.A. Barragán Escandón, Generación eólica en Ecuador: análisis del entorno y perspectivas de desarrollo, Rev. Técnica Energía 10 (2014) 58–66, doi.org/10.37116/revistaenergia.v10.n1.2014.100.
[22] ONU, Objetivos de desarrollo sostenible [WWW Document]. URL, http://www.un.org/sustainabledevelopment/es/2015/09/la-asamblea-general-adopta-la-agenda-2030-para-el-desarrollo-sostenible/#prettyPhoto, 2015. accessed 11.10.16.
[23] ONU, Proyecto de documento final de la Conferencia de las Naciones Unidas sobre la Vivienda y el Desarrollo Urbano Sostenible (Hábitat III), 2016. Quito, Ecuador.
[24] Secretaría Nacional de Planificación, Plan de Creación de Oportunidades 2021 - 2025, Secretaría Nacional de Planificación, Quito, 2021.
[25] Sandra Méndez-Fajardo, Heinz Böni, Paul Vanegas, Dolores Sucozhañay, Improving sustainability of E-waste management through the systemic design of solutions: The cases of Colombia and Ecuador. Handbook of Electronic Waste Management: International Best Practices and Case Studies, Elsevier, 2019, pp. 443–478. In press.
[26] J.M.A. Ponce, La energía solar fotovoltaica distribuida y las Smart Grid como modelo para diversificar la Matriz Energética de Ecuador, Universidad Nacional de Educación a Distancia, 2019.
[27] ARCONEL, Generación fotovoltaica para autoabastecimiento de consumidores finales de energía eléctrica, 2018. Ecuador.
[28] F. Moraes, J. Cezar, M. Siluk, F.D.S. Savian, R. Pinheiro, C. Ramos, Factors for measuring photovoltaic adoption from the perspective of operators, Sustainability 3184 (2020) 1–29.
[29] C.P. Kiefer, P. del Río, Analysing the barriers and drivers to concentrating solar power in the European Union. Policy implications, J. Clean. Prod. 251 (2020), 119400, https://doi.org/10.1016/j.jclepro.2019.119400.
[30] Y. Lu, R. Chang, V. Shabunko, A.T. Lay Yee, The implementation of building-integrated photovoltaics in Singapore: drivers versus barriers, Energy 168 (2019) 400–408, https://doi.org/10.1016/j.energy.2018.11.099.
[31] D.N. yin Mah, G. Wang, K. Lo, M.K.H. Leung, P. Hills, A.Y. Lo, Barriers and policy enablers for solar photovoltaics (PV) in cities: perspectives of potential adopters in Hong Kong, Renew. Sustain. Energy Rev. 92 (2018) 921–936, https://doi.org/10.1016/j.rser.2018.04.041.
[32] J.O.Y. Wyllie, E.A. Essah, E.L. Ofetotse, Barriers of solar energy uptake and the potential for mitigation solutions in Barbados, Renew. Sustain. Energy Rev. 91 (2018) 935–949, https://doi.org/10.1016/j.rser.2018.04.100.
[33] P. del Río, C. Peñasco, P. Mir-Artigues, An overview of drivers and barriers to concentrated solar power in the European Union, Renew. Sustain. Energy Rev. 81 (2018) 1019–1029, https://doi.org/10.1016/j.rser.2017.06.038.
[34] P.T.I. Lam, H.X. Yang, J.S. Yu, Critical Success Factors for integrating renewable energy development in a country with 2 systems: the case of Pearl River Delta and Hong Kong SAR in China, Energy Pol. 107 (2017) 480–487, https://doi.org/10.1016/j.enpol.2017.05.024.
[35] S. Nasirov, C. Silva, C.A. Agostini, Investors’ perspectives on barriers to the deployment of renewable energy sources in Chile, Energies 8 (2015) 3794–3814, https://doi.org/10.3390/en8053794.
[36] N. Kumar, N. Pal, The existence of barriers and proposed recommendations for the development of renewable energy in Indian perspective, Environ. Dev. Sustain. 22 (2020) 2187–2205, https://doi.org/10.1007/s10668-018-0284-y.
[37] E. Karakaya, P. Sriwannawit, Barriers to the adoption of photovoltaic systems: the state of the art, Renew. Sustain. Energy Rev. 49 (2015) 60–66, https://doi.org/10.1016/j.rser.2015.04.058.

[38] Pablo del Río, Cristina Peñasco, Pere Mir-Artigues, An overview of drivers and barriers to concentrated solar power in the European Union, Renew. Sustain. Energy Rev. 81 (June 2017) (2018) 1019–2029, https://doi.org/10.1016/j.rser.2017.06.038. In this issue.
[39] T.B. Garlet, J.L.D. Ribeiro, F. de Souza Savian, J.C. Mairesse Siluk, Paths and barriers to the diffusion of distributed generation of photovoltaic energy in southern Brazil, Renew. Sustain. Energy Rev. 111 (2019) 157–169, https://doi.org/10.1016/j.rser.2019.05.013.
[40] J. Haas, R. Palma-Behnke, F. Valencia, P. Araya, G. Díaz-Ferrán, T. Telsnig, L. Eltrop, M. Díaz, S. Püschel, M. Grandel, R. Román, G. Jiménez-Estévez, Sunset or sunrise? Understanding the barriers and options for the massive deployment of solar technologies in Chile, Energy Pol. 112 (2018) 399–414, https://doi.org/10.1016/j.enpol.2017.10.001.
[41] S.K. Kar, A. Sharma, B. Roy, Solar energy market developments in India, Renew. Sustain. Energy Rev. 62 (2016) 121–133, https://doi.org/10.1016/j.rser.2016.04.043.
[42] Meer, n.d. Plan Nacional de Eficiencia Energética 2016-2035Ministerio de Electricidad y Energía Ministerio de Electricidad y Energía Renovable, Ministerio de Electricidad y Energía Renovable. https://doi.org/10.1515/fca-2015-0035.
[43] R. Gomelsky, Sustainable Energy for All: Rapid Assessment Gap Analysis Ecuador, MEER - IDB. Quito, Ecuador, 2013.
[44] Tech4Cdm, La energía eólica en Ecuador, 2012, https://doi.org/10.1103/PhysRevB.73.033101.
[45] J.M. Orozco, Panorama de las energías renovables y de la eficiencia energética en América Latina, Universidad Católica del Ecuador, Quito, Ecuador, 2013.
[46] A. Pachano Mena, La investigación y desarrollo de energías renovables en el Ecuador: Análisis crítico. Corporación para la Investig, Energética, 2013.
[47] CONELEC, Plan Maestro de Electrificación 2013 - 2022. Aspectos de sustentabilidad y sostenibilidad social y ambiental, Quito, Ecuador, 2013.
[48] I. Cabrera, E. Figueroa, Situación energética en el Ecuador, análisis técnico y económico para el uso eficiente de la energía, Univ. Cuenca. Universidad de Cuenca, 2012.
[49] E. Rosero, B. Chiliquinga, Informe final: línea base de las tecnologías energéticas y estado del arte, Quito, Ecuador, 2011.
[50] A.M. Rosso-Cerón, V. Kafarov, Barriers to social acceptance of renewable energy systems in Colombia, Curr. Opin. Chem. Eng. 10 (2015) 103–110, https://doi.org/10.1016/j.coche.2015.08.003.
[51] C.A. Frate, C. Brannstrom, Stakeholder subjectivities regarding barriers and drivers to the introduction of utility-scale solar photovoltaic power in Brazil, Energy Pol. 111 (2017) 346–352, https://doi.org/10.1016/j.enpol.2017.09.048.
[52] T. Gómez-Navarro, D. Ribó-Pérez, Assessing the obstacles to the participation of renewable energy sources in the electricity market of Colombia, Renew. Sustain. Energy Rev. 90 (2018) 131–141, https://doi.org/10.1016/j.rser.2018.03.015.
[53] C. Guzowski, M. Recalde, Barreras a la entrada de las energías renovables: el caso argentino, Asades 12 (2008) 31–38.
[54] J.R.F. Diógenes, J. Claro, J.C. Rodrigues, Barriers to onshore wind farm implementation in Brazil, Energy Pol. 128 (2019) 253–266, https://doi.org/10.1016/j.enpol.2018.12.062.
[55] E. Barragán-Escandón, E. Zalamea-León, J. Terrados, P. Vanegas-Peralta, Factores que influyen en la selección de energías renovables en la ciudad 45 (2019) 259–288.
[56] H. Al Garni, A. Kassem, A. Awasthi, D. Komljenovic, K. Al-Haddad, A multicriteria decision making approach for evaluating renewable power generation sources in Saudi Arabia, Sustain. Energy Technol. Assessments 16 (2016) 137–150, https://doi.org/10.1016/j.seta.2016.05.006.
[57] X. Zhao, X. Ma, Y. Shang, Z. Yang, U. Shahzad, Green economic growth and its inherent driving factors in Chinese cities: based on the Metafrontier-global-SBM super-efficiency DEA model, Gondwana Res. 106 (2022) 315–328, https://doi.org/10.1016/j.gr.2022.01.013.
[58] D. Rosenbloom, J. Meadowcroft, Harnessing the Sun: reviewing the potential of solar photovoltaics in Canada, Renew. Sustain. Energy Rev. 40 (2014) 488–496, https://doi.org/10.1016/j.rser.2014.07.135.
[59] D. Moscovici, R. Dilworth, J. Mead, S. Zhao, Can sustainability plans make sustainable cities ? The ecological footprint implications of renewable energy within Philadelphia's Greenworks Plan, Sustain. Sci. Pract. Pol. 11 (2015) 32–43, https://doi.org/10.1080/15487733.2015.11908137.
[60] J. Terrados, G. Almonacid, P. Pérez-Higueras, Proposal for a combined methodology for renewable energy planning. Application to a Spanish region, Renew. Sustain. Energy Rev. 13 (2009) 2022–2030, https://doi.org/10.1016/j.rser.2009.01.025.
[61] H. Haberl, The energetic metabolism of societies, Part I: accounting concepts, J. Ind. Ecol. 5 (2001) 11–33, https://doi.org/10.1162/108819801753358481.
[62] IEA, Cities, Towns & Renewable Energy: Yes in My Front Yard, IEA/OECD, Paris, France, 2009.
[63] IRENA, Renewable Energy in Cities, EAU, Abu Dhabi, 2016.
[64] D. Sveinbjörnsson, S. Ben Amer-Allam, A.B. Hansen, L. Algren, A.S. Pedersen, Energy supply modelling of a low-CO2 emitting energy system: case study of a Danish municipality, Appl. Energy 195 (2017) 922–941, https://doi.org/10.1016/j.apenergy.2017.03.086.
[65] N. Carlisle, O. Geet, S. Van Pless, Definition of a " Zero Net Energy " Community, National Renewable Energy Laboratory, Golden, Colorado, 2009.
[66] Y. Xu, S. Li, X. Zhou, U. Shahzad, X. Zhao, How environmental regulations affect the development of green finance: recent evidence from polluting firms in China, Renew. Energy 189 (2022) 917–926, https://doi.org/10.1016/j.renene.2022.03.020.
[67] OLADE, Barómetro de la energía de América Latina y el Caribe 2019. Las perspectivas del desarrollo del sector energetico en la región, Quito, Ecuador, 2019.
[68] La energía renovable, sin reglas claras, 2017. https://www.revistalideres.ec/lideres/energia-renovable-reglas-claras-eduardorosero.html. (Accessed 20 March 2017).
[69] A. Mena, Entrevista al Ing. Alfredo Mena Pachano, director ejecutivo de la CIE, 2017. Vistazo.
[70] IEA, Cities , Towns & Renewable Energy Cities, Towns. IEA/OECD, Paris, 2009.
[71] A. Barragán-Escandón, J. Terrados, E. Zalamea, P. Arias, Electricity production using renewable resources in urban centres, Proc. Inst. Civ. Eng. - Energy 171 (2018) 12–25, https://doi.org/10.1680/jener.17.00003.
[72] Alecksey Mosquera, Políticas y Estrategias para el cambio de la matriz energética del Ecuador, Ministerio de Electricidad y Energía Renovable, 2008. In press.
[73] Presidencia de la República del Ecuador, Reglamento de precios de derivados de petróleo. Ecuador, 2018.
[74] F. Schaffitzel, M. Jakob, R. Soria, A. Vogt-schilb, H. Ward, Pueden las transferencias del gobierno hacer que la reforma de los subsidios energéticos sea socialmente aceptable: un estudio de caso sobre Ecuador, Banco Interam. Desarro. Div. Cambio Clim. (2019).
[75] Presidencia de la República del Ecuador, Decreto N° 451-A. Ecuador, 2007.
[76] D. Espinoza, C. Viteri, Análisis económico de la eliminación del subsidio de la gasolina súper en el Ecuador, Rev. Espac. 40 (2019) 12.
[77] M. Castro, Hacia una matriz energética diversificada en Ecuador, CEDA Centro Ecuatoriano de Desarrollo Ambiental, Quito, Ecuador, 2011. Centro Ecuatoriano de desarrollo Ambiental.
[78] P.A. Carrillo Maldonado, J. Díaz Cassou, J. Tejeda, El impacto macroeconómico de la reforma energética ecuatoriana, BID, 2018, https://doi.org/10.18235/0001212.
[79] Q. Zhu, X. Chen, M. Song, X. Li, Z. Shen, Impacts of renewable electricity standard and Renewable Energy Certificates on renewable energy investments and carbon emissions, J. Environ. Manag. 306 (2022), 114495, https://doi.org/10.1016/j.jenvman.2022.114495.
[80] B. Chen, C. Xu, Y. Wu, Z. Li, M. Song, Z. Shen, Spatiotemporal carbon emissions across the spectrum of Chinese cities: insights from socioeconomic characteristics and ecological capacity, J. Environ. Manag. 306 (2022), 114510, https://doi.org/10.1016/j.jenvman.2022.114510.