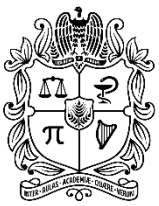

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Green Power Markets in Latin America: Experiences and Trends

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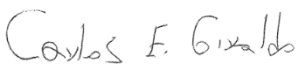


Nombre: Carlos Enrique Giraldo Vélez

Fecha 20/01/2023

Resumen

Mercados de energía verde en América Latina - Experiencias y tendencias

En los últimos años estamos observando cambios esenciales en los sistemas eléctricos, donde los acuerdos internacionales y las medidas medioambientales están empujando hacia una transición energética con tendencia a incorporar tecnologías energéticas más limpias, eficiencia energética y nuevas formas de hacer negocio energético. Respecto a la preocupación por la seguridad del suministro energético, la reducción de los impactos ambientales, la mejora de las condiciones de adaptabilidad al cambio climático y la incorporación de elementos de competencia en la prestación de servicios energéticos. En este documento, analizamos el mercado emergente de energía verde en América Latina y revisamos la política de electricidad verde de los países identificados con este mercado. Examinamos la eficacia de la política en la evolución de la capacidad instalada renovable como parte de la matriz eléctrica. Sorprende el crecimiento de las renovables en toda la región, pero también el crecimiento general de la capacidad instalada térmica. También analizamos los factores clave que influyen en la penetración en el mercado de los productos de energía verde, como el diseño del mercado, la fijación de precios, los incentivos, las políticas y la interacción entre ellos. En América Latina, identificamos una mayor penetración del mercado en Chile y Panamá; sin embargo, hasta ahora no es un mercado muy dinámico. Se necesita un liderazgo político comprometido para promover enérgicamente la inclusión de incentivos que aceleren la transición energética.

Palabras clave: Productos energéticos verdes, Política de energías renovables, Certificados de Atributo Energético.

Abstract

Green Power Markets in Latin America: Experiences and Trends

In recent years we have been observing essential changes in the electricity systems, where international agreements and environmental measures are pushing towards an energy transition with a tendency to incorporate cleaner energy technologies, energy efficiency, and new ways of doing energy business. Concern for the security of energy supply, reducing environmental impacts, improving the conditions for adaptability to climate change, and incorporating elements of competition in the provision of energy services. In this document, we analyze the emerging green energy market in Latin America and review the green electricity policy of the countries identified with this market. We look at the policy's effectiveness in the evolution of renewable installed capacity as part of the electricity matrix. It was a surprise that there is growth in renewables across the region, but there is also an overall growth in thermal installed capacity. We also look at the key factors influencing the market penetration of green energy products, such as market design, pricing, incentives, policies, and the interaction between these. In Latin America, we identified higher market penetration in Chile and Panama; however, it is not a very dynamic market so far. More excellent political leadership is needed to vigorously promote the inclusion of incentives to accelerate the energy transition.

Keywords: Green power products, Renewable energy policy, Energy Attribute Certificates.

Index

Introduction

Electricity markets have been diversified, pushing for more renewable worldwide, and creating more dynamic scenarios. The current commitments promote this within the Paris Agreement (COP26) and the need to decarbonize the electricity sector. New technologies and market platforms have made it possible for customers or energy consumers to choose their electricity supplier and the type of product they prefer within the portfolio of market participants, such as simple traceability mechanisms, Ethereum Blockchain, and Smart Contracts [1]. Product differentiation makes competition in the market much more challenging and innovative, based on prices and other forms of product or service differentiation, where environmental support plays a role in decisions. The variety of green products is wide; for example, tradable green certificate schemes are characterized by premium energy tariffs based on consumer preferences and firm strategies [2]–[4]. Typically, these green power products are claimed only to be generated totally or partially from renewable sources, equivalent to one MWh generated. In addition, they generate other types of benefits, such as the financing and promotion of power generation projects. They can be a powerful policy instrument to promote the acquisition of low-carbon electricity by the GHG protocol, Scope 2 users [5]–[7].

Many green power products have already been designed for different purposes and studied in European countries and North America [8]. These products are not new; for instance, in Germany, in the '90s, the first natural energy products were offered based on differentiated tariffs for customers [9]. In the year 2000 were many competitive products in the market, as in the UK, one of the first countries in Europe to dynamize its electricity market, allowing the marketing of green power to all consumers since 1999 [10]. Likewise, in Finland, consumers have been buying green power since 1998 [11]. As a support system for renewable electric energy sources, Poland implemented a system of Tradable Green Certificates, which worked very well for a time [12]. On the other hand, Texas quickly became one of the leading wind energy markets in the United States due to a well-designed and carefully implemented renewables portfolio standard (RPS) [13].

For example, about 20 green power products are available in Australia, where about three-quarters are accredited by the National Green Power Accreditation Program. Furthermore, other marketers recently began offering uncertified products, mainly to nonresidential customers [14]. Likewise, several European countries have shown some emerging green power marketing activity. The EU Renewable Energy Directive from 2009 states that Guarantees of Origin (GO) prove to consumers that a given quantity of energy was produced from renewable energy sources. GOs are a purely voluntary system used by businesses, public institutions, and European households to encourage customers that a given amount of energy was made from renewable energy sources. GOs could be a strictly voluntary system employed by businesses, public establishments, and European households [15]. In Austria, the electricity market was fully liberalized in October 2001, and some 2500 customers buy green power from either new entrants like Oekostrom AG, Alpen-Adria-Energy AG (AAE), and Raiffeisen Ware Austria, or the incumbent utilities. The largest power generator in the country, Verbund, has been actively branding its existing hydro and selling it to wholesalers and retailers in Germany, Italy, and Austria. No significant green power marketing activity in Belgium has emerged, although the Flemish region has allowed residential customers to switch to a competitive green supplier since September 2001. However, the country's largest utility, Electrabel, has been active in hydropower marketing and renewable energy certificate trading in other European countries [16].

Other clear examples of well-known regional markets are China and Japan. In 2000, all ten of Japan's electric utilities began offering their customers the option to contribute to a green power fund to support the development of wind and solar systems. For example, Tokyo Electric Power Company (TEPCO) offered a program through which customers could contribute an additional five hundred Yen or more each month through their electricity bills. TEPCO matched customer donations and administered the program, while a non-profit organization managed and operated the fund [56]. Now in Japan, there are three types of certificates J-Credit (derived from renewable energy), Green Electricity Certificates (GEC), and Non-Fossil Certificates (NFC), of which major international initiatives on climate change acknowledge J-Credit and GEC. Although Non-Fossil Certificate is recognized for its environmental value of not emitting GHGs, including CO2, there is no means to prove that the electricity is generated with low environmental impact. In other words, the generator's tracking (or attribute) information is lacking [17].

Meanwhile, China also opened 2017 its GEC system as a pilot to allow businesses and individuals to buy renewable energy voluntarily. The system is designed and maintained by the China Renewable Energy Engineering Institute (CREEI). GECs allow companies to claim the environmental benefits associated with renewable energy generation. Large-scale onshore grid-connected wind and solar PV projects receiving a Feed-in-Tariff are eligible to participate in the GEC system. The renewable electricity generators participating in China's GEC system can also issue multiple environmental market instruments, such as GHG offsets for the same generation [18].

Existing literature on green power products has shown how the products are rapidly growing, and regulation has been changing, causing previous research to lag and require an update like Has et al. study [6], [19]. For example, at the start of the EU market, there were no binding national requirements for the share of renewable energy, such as the Renewable Energy Sources (RES) Directive. Therefore, there was a more robust perception in the past that increased consumer demand would induce more renewable electricity in the market [19].

Energy generation contributes nearly 40% of global greenhouse gas (GHG) emissions [7]. It is one of the primary mitigation strategies within the framework of the commitments assumed by each country in the Paris Agreement under the so-called Nationally Determined Contribution (NDC) targets. Therefore, the transition to a low-carbon economy requires companies to change their electricity consumption from fossil fuels to renewable energy and other measures. As a result, more and more corporations are increasing their renewable energy consumption and reporting these measures as part of their sustainability and social responsibility strategy. Organizations that take such measures report and reclaim their renewable energy consumption using different traceability and monitoring mechanisms. Organizations usually purchase or use Energy Attribute Certificates (EACs) to meet different targets or voluntary commitments, such as the GHG protocol, the CDP, or RE100.

Other companies, for example, are certified under the EKOEnergy label, helping to finance the construction of new renewable energy generation projects and investing in the protection and preservation of different ecological systems [20]. Thus, energy products diversification help to reduce green power price [21], reducing the price gap between renewable and conventional energy.

The market for green power products in Latin America has not yet been reviewed or studied; this is still an unknown market for many players. So this manuscript takes relevance as we seek to provide a comprehensive study of green power products in Latin America, covering all jurisdictions in the region where there is a voluntary or mandatory green power market. **Figure 1** shows several mechanisms of international scope identified, such as I-REC and TGIR, and regional mechanisms, such as USA REC, EU GoO, and MX CEL. In countries such as Mexico and Colombia, the presence of several mechanisms at the same time was found. The participation of these mechanisms has increased in Latin America in recent years, and there are already twelve countries with the presence of EACs, which will be reviewed in more detail below: Argentina, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, El Salvador, Guatemala, Honduras, Mexico, Panama, and Peru.

The main objective is to review the international strongest markets' behavior and assess market growth in Latin America, characterizing the type of green power products, the different energy production structures, and the legislation that regulates or promotes this market. We assess how the consumer demand for green power products has developed in the last years, as well as define the main factors influencing market behavior. We observe factors such as competition and switching, price levels, interaction effects with other renewable energy policies, regulation and labeling, and policies directly supporting green electricity sales. Finally, we explicitly show the opportunities and difficulties of emerging green power markets in Latin America. The results of this study can specifically help in developing new studies that propose a series of policies or mechanisms that improve and promote the integration of this market with other complementary regulatory strategies such as renewable energy auctions and feed-in tariffs (FiTs). Likewise, the promotion of more actors (consumers, certification mechanisms, government, Etc.) will lead to more stable growth of a market for green energy products in the region and hopefully a greener energy matrix.

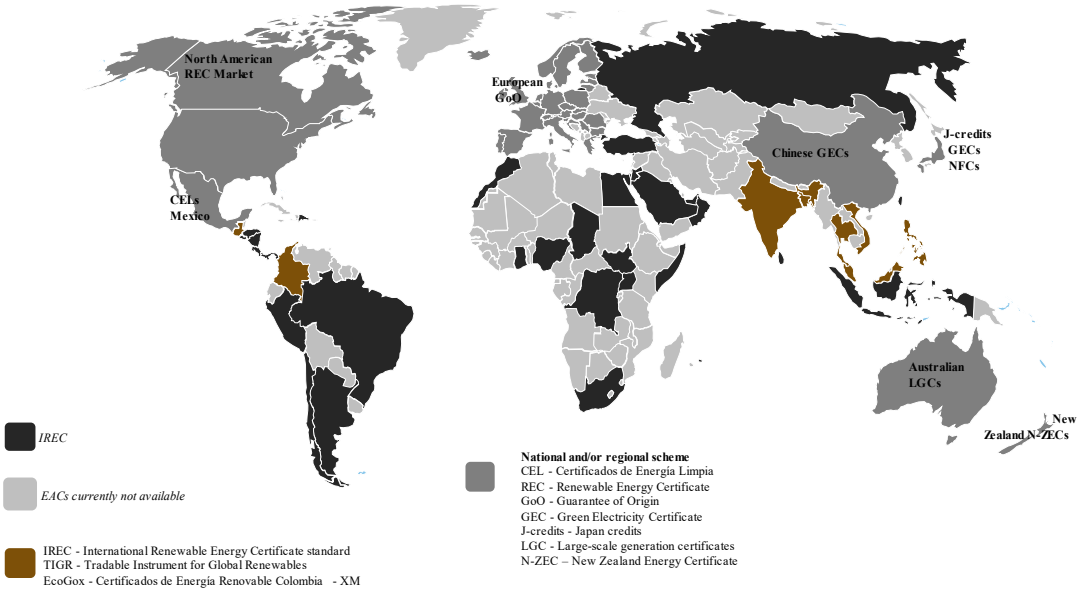


Figure 1: Global EACs. Source: Author

1. Materials and methods

Scope: The present proposal has a qualitative and quantitative approach, where we first review Latin American countries where different degrees of green power have been underway. Information on market monitoring and performance will be obtained through literature, news reports, and discussions with traders, environmental stakeholders, and market operators. We also look at representatives of product certification programs, utilities, government entities, and different public and private sources from the primary sellers of green power. We consider the nature of offered products, content and price, consumer response, and the development of new renewable resources stimulated by green power purchases. Both voluntary and mandatory markets in Latin America for these green attributes are considered.

Areas to explore green power products market development, price levels, effects of interaction with renewable energy policies, regulation and labeling, and policies to support green power sales directly.

Determination of main variables: we identify the driving forces for market behavior.

Data collection Latin America: Data (green power product types, units sold, applications, prices, market actors, Etc.) will be collected to measure the performance and growth of green power markets. The data consists of two broad categories related to two review objectives. The first objective is to measure the scope of green product jurisdictions and the size of their markets, which is done by a search in all developed countries in Latin America. An online search, collecting database, and communication with regulators and other market actors to identify green power products offered by traders or power generators. The idea is to recognize the mechanisms involved in the different targets or voluntary commitments, such as the GHG protocol, the CDP, or RE100, and to determine which countries have green power products trade. The second objective is to identify the market actors, which include suppliers/retailers, size of suppliers, technology used and

length they have been operating, consumers, and labeling programs. We also study the interaction of market actors with local regulation (electricity regulators, interaction effects with other renewable energy policies, labeling, price and regulation, and policies to support green product sales). To our knowledge, this is a pioneer study on green power market review in Latin America.

Data analysis: With the result of the data analysis, the Latin American countries with the most significant green power market potential and the difficulties that present will be determined. This will allow us to propose in future studies a series of policies or mechanisms that integrate other complementary regulatory strategies such as renewable energy auctions and Feed-in tariffs (FiTs). Thus, promoting the participation of many more actors in the future (consumers, certification mechanisms, government, Etc.) and the stable growth of a green power products market in the region.

2. Background and results

Latin America hosts some of the world's most dynamic renewable energy markets, built on the historical role of hydropower, the cornerstone of the region's power sector development, and biomass. The last has played an essential role at the beginning of an energy transition, driven by Brazil's early determination to diversify its power mix [22]. These facts already positioned the region as a global low-carbon leader in terms of power generation, also considering that significant progress has recently been made in developing its other renewable energy sources [22]. Declining costs, maturing technologies, and the unexploited potential of renewables offer an unprecedented opportunity for further development of the renewables market in the region [23].

The electricity demand is growing, and electricity production and consumption are usually positively correlated with economic growth. Over the last 20 years, average economic and electricity growth in Latin America has exceeded the world average [23]. Electricity consumption in the countries reviewed has more than doubled, from 422 TWh in 1990 to 1,175 TWh in 2018, representing an average growth of 3.5% per year, of which 50% is generated by hydropower, 46% by thermal sources in 2018, and the remaining by renewables such as biomass, wind, and solar. By contrast, hydropower generation share in the United States is about 7%, and in European Union countries, it was over 15% in 2017 [23].

The positive correlation between growth in GDP per capita and growth in power consumption per capita is a trend more noticeable in developing economies, such as those of Latin America (

Table 1), than in developed nations, due in part to lower levels of energy efficiency, growing use of electric appliances, and increases in electricity access. The population of Latin America is growing by 0.85 % annually over the next 20 years, while the region's economies are expected to expand by 3% a year on average. Meeting this growing demand will require nearly doubling the region's combined electricity generation capacity from 1,175 TWh in 2018 to 2,500 TWh in 2030 [23].

Countries such as Dominican Republic, Panama, and Peru follow the trend of electricity consumption growth as GDP increases. Colombia, Dominican Republic, Panama, and Peru, increased their

electricity consumption by around 0.6-0.7 times concerning the change in GDP between 2008 and 2018. By contrast, Argentina and, Brazil, Chile had a relation of 0.21 and 0.26 times respectively in the same period. These numbers indicate the importance of electricity consumption regarding GDP and GDP's impact on driving consumption. However, the feedback between these two variables is more accentuated in countries with a low GDP. The total primary energy supply (TPES) per capita shows the sum of primary energy available to each person in a country. Argentina, Brazil, Colombia, and Mexico have a higher TPES, which indicates their capacity to supply different economic and social processes.

Electricity consumption per capita is higher in Argentina, Brazil, Chile, Costa Rica, Mexico, and Panama, i.e., the countries with the highest GDP per capita in the region. However, in Argentina, Chile, and notably Panama, the CO2 emission per capita is higher than in countries with the highest electricity consumption in South America due to the energy matrix. Nevertheless, the emissions per capita of the region are lower than those of China and the United States; total emissions are 1088 Mt of CO2, while China and the United States emit 9087 Mt and 5176 Mt of CO2, respectively [24].

Demographic and economic growth will continue to increase the demand for electricity, which implies a challenge for policymakers to ensure the necessary capacity and the environmental sustainability of new plants. To be able to deliver on the second criteria, governments need to commit to energy efficiency and promote renewable technologies that are aligned with the Paris Agreement [24].

Table 1: Main macroeconomic indicators, energy consumption, and emissions per capita for 2018.

Country	GDP (Billion 2015 USD PPP)	GDP per Capita	GDP per capita increase over the last decade (%)	TPES per capita (toe/ capita)	Electricity consumption per capita (kWh/capita)	Electricity consumption TWh increase over the last decade (%)	CO2 emissions per capita (tCO2/capita)*
Argentina	866.97	19.52	-1%	1.88	2.82	21%	4.33
Brazil	3,004.13	14.33	4%	1.46	2.52	26%	2.18
Chile	436.90	23.30	21%	0.60	4.03	41%	4.64
Colombia	668.72	13.49	26%	2.57	1.42	64%	1.45

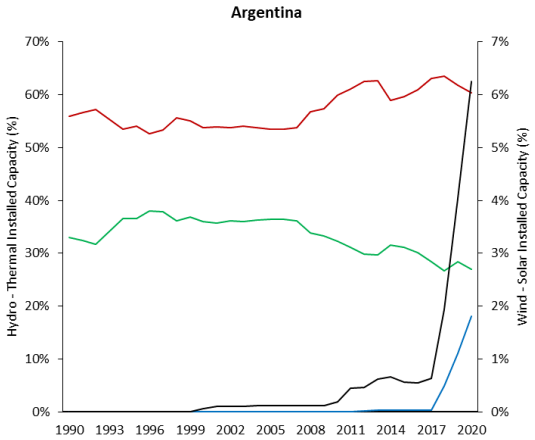
Costa Rica	89.37	17.88	24%	0.52	2.01	21%	1.68
Dominican Republic	176.21	16.58	48%	0.06	1.51	61%	2.38
El Salvador	51.61	8.04	17%	0.13	0.89	11%	1.10
Guatemala	137.74	7.99	11%	0.15	0.61	48%	1.09
Honduras	46.66	4.87	13%	0.15	0.70	35%	1.05
Mexico	2,388.35	18.90	9%	1.25	2.14	32%	3.76
Panama	101.35	24.27	50%	0.47	2.22	71%	6.20
Peru	394.11	12.33	37%	0.87	1.48	61%	1.66

Source: IEA [25]*. CO2 emissions from fuel combustion only. Emissions are calculated using the IEA's energy balances and the Revised 2006 IPCC Guidelines.

2.1 Power capacity evolution in Latin America's energy pool

Currently, electricity and heat generation are some of the most significant global contributors to greenhouse gas emissions due to the high consumption of fossil fuels in power plants and the growing electricity demand. However, Latin America has the greenest electricity matrix in the world (in terms of carbon intensity) [23]. This is mainly due to its sizeable hydroelectric development, which has been the largest source of electricity generation since before the 1990s, as seen in **Figure 2**. This figure shows that hydroelectricity represents about 37% of the total installed generation capacity in the reviewed countries. However, the share of electricity from hydropower has been decreasing in the last decade, a trend that is expected to continue with the development of natural gas and renewable resources.

The hydropower share of capacity declined from 39% in 2010 to 37% in 2020, while thermal energy also represented a decline from 54% to 44% at the end of the same period. It showed a constant growth, an evident trend in Argentina, Brazil, and Mexico (see **Figure *3***), which still reflects a high dependence on thermal energy and a slow decarbonization process. Overall, the role of fossil fuels in the region has changed over time, with fuel slowly being replaced by natural gas, while coal use remains low [26].


Argentina
Hydro - Thermal Installed Capacity (%)
Wind - Solar Installed Capacity (%)
70%
60%
50%
40%
30%
20%
10%
0%
7%
6%
5%
4%
3%
2%
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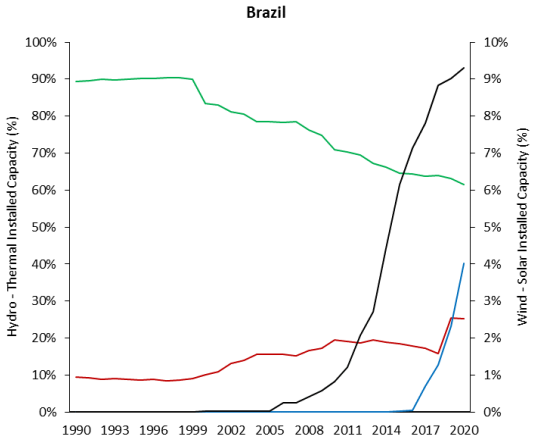
1990 1993 1996 1999 2002 2005 2008 2011 2014 2017 2020


Brazil
Hydro - Thermal Installed Capacity (%)
Wind - Solar Installed Capacity (%)
100%
90%
80%
70%
60%
50%
40%
30%
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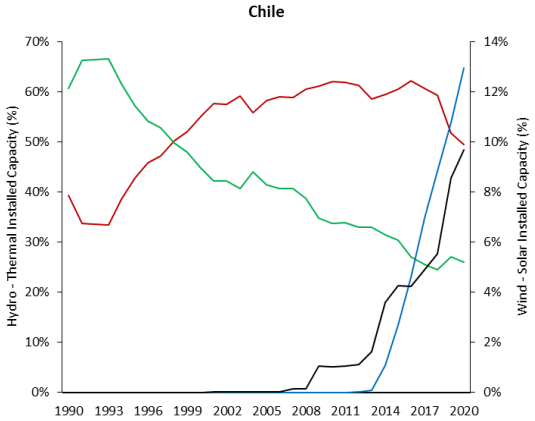
Chile
Hydro - Thermal Installed Capacity (%)
Wind - Solar Installed Capacity (%)
70%
60%
50%
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30%
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14%
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4%
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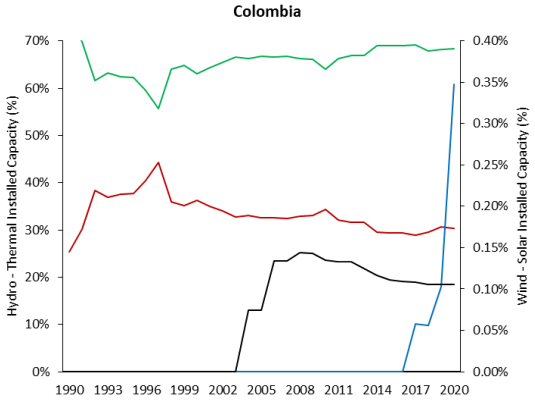
Colombia
Hydro - Thermal Installed Capacity (%)
Wind - Solar Installed Capacity (%)
70%
60%
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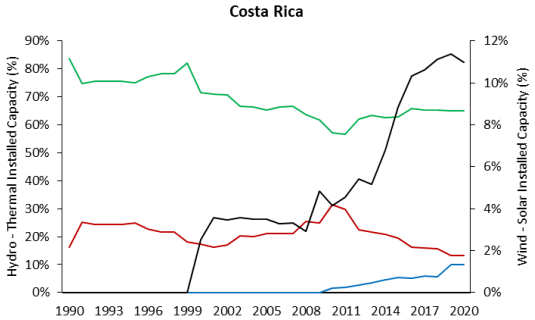
Costa Rica
Hydro - Thermal Installed Capacity (%)
Wind - Solar Installed Capacity (%)
90%
80%
70%
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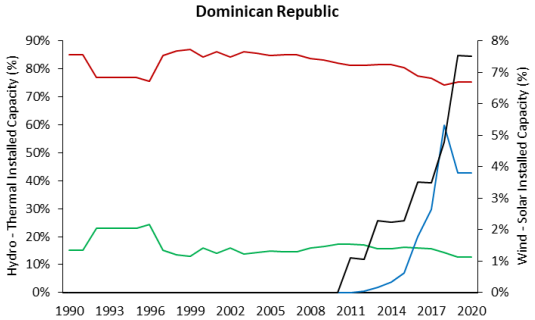
Dominican Republic
Hydro - Thermal Installed Capacity (%)
Wind - Solar Installed Capacity (%)
90%
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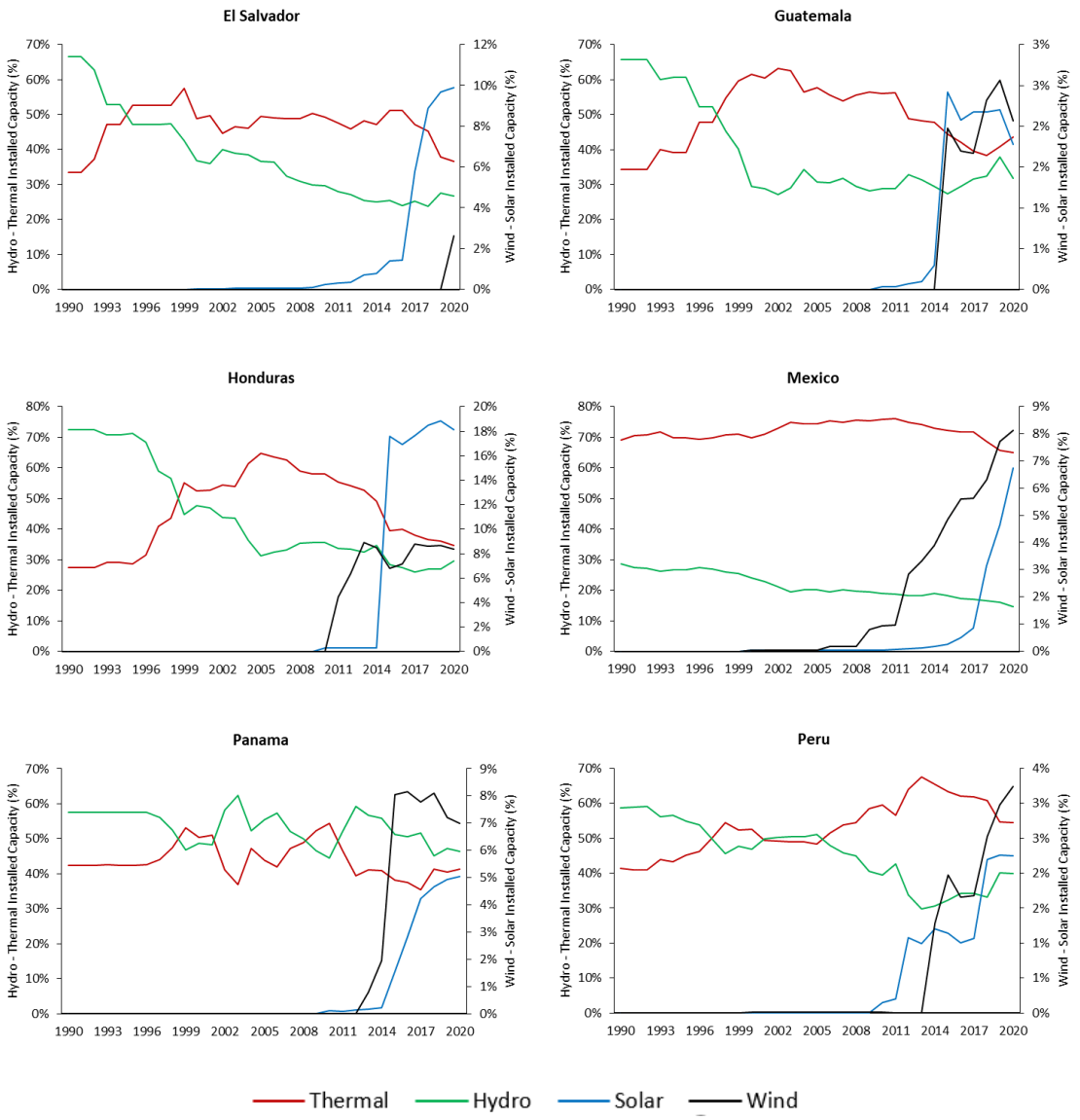

Figure 2: Installed thermal, solar, and wind capacity in identified countries in Latin America. This figure shows the historical installed capacity in Latin America. The red lines represent installed thermal capacity, the blue represents solar, and the black represents wind. Source: EIA [25], Argentina [27], [28], Brazil [29], Chile [30], Colombia [31], Costa Rica [32], [33], Dominican Republic [34], El Salvador [35], Guatemala [36], Honduras [37], Mexico [38], Panama [39], Peru [40].

There are reasons for selecting thermal generation technology in some Latin American countries. One reason is El Niño Southern Oscillation (ENSO) phenomenon, which causes

water shortages or flooding; therefore, the hydrological potential is not always available, and the start-up of these plants is more delayed and requires more CAPEX intensity. For example, in Colombia and Chile, depending on the ENSO phase and in addition to the growing demand for energy that creates the need to build more generation capacity, there is high uncertainty in the availability of the resource for renewables, which, although they are increasing their share in the power mix, has not yet been sufficient. Thermal capacity can ensure the security of supply in these periods, and most electricity systems currently require a minimum level of thermal capacity to ensure such security. Generally, renewables have been more expensive than thermal, and construction time is considerably shorter than "large" hydro. However, the increase in the share of installed thermal capacity and the prolonged growth of renewables demonstrate that the energy transition from thermal to renewable sources is generally not a reality in Latin America [24].

As is shown in **Figure *3***, all the present countries grow in installed thermal capacity; the ones with larger capacity are Mexico, Brazil, and Argentina. There has been a lot of discussions and effort to deploy more and more renewables; however, such increment is counterintuitive. This evidence depicts a critical environmental paradox; despite the increase of renewable deployment in the region (in some cases at an immense scale), the thermal generation is still growing, which necessarily means the growth of GHG emissions. This paradox has been previously identified and is still valid one decade after [41].

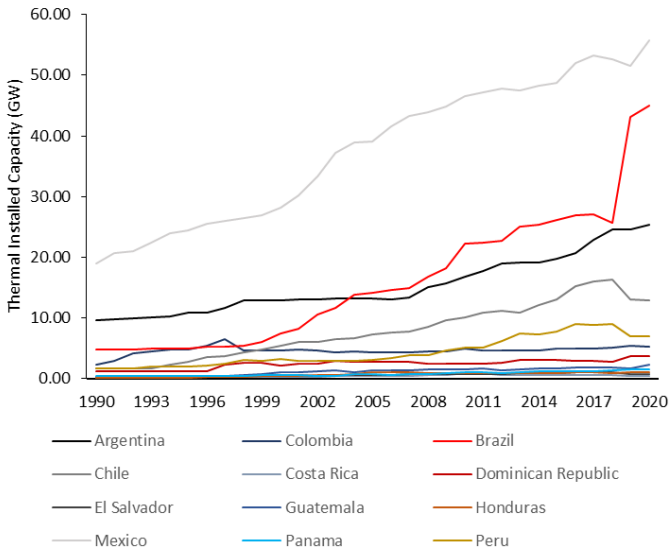

Figure 3: Installed thermal capacity in identified countries in Latin America. Source: EIA [25], Argentina [27], [28], Brazil [29], Chile [30], Colombia [31], Costa Rica [32], [33], Dominican Republic [34], El Salvador [35], Guatemala [36], Honduras [37], Mexico [38], Panama [39], Peru [40].

Although renewables other than large hydro currently account for only 12% of total installed energy capacity, they have begun to grow in recent years. Between 2006 and 2018, installed renewable capacity doubled from 7.1 GW to 52.9 GW. Biomass and waste represent most of this growth (mainly in Brazil), but there has also been significant development in solar and wind power. Beginning of the last decade (2010-2020), wind power was more robust than solar power; however, now they have similar growth in the region. Falling solar energy costs make this resource more attractive [23]. Chile and Honduras have the highest share of solar and wind power among the countries reviewed, with 23% (13% solar and 10% wind) and 26% (18% solar and 8% wind), respectively. Meanwhile, Colombia has the lowest share of solar and wind power in its mix (< 1%); however, it is expected that by 2022 important projects will enter the pipeline that will contribute to its RES targets.

2.2 Electricity markets and capacity mechanisms

Electricity markets need a particular regulatory framework for each case, considering each country has its characteristics, such as the basic electricity resource properties, a sensitive and inelastic demand, and the problem of lack of investment or budget for implementation.

Adding also the substantial fall of electricity prices in a change from a centralized system with power plants operating mainly with fossil fuels to a decentralized system with a high rate of RE, the concern of regulators or the government increases due to the need to adjust electricity generation, which has led to the application of a variety of capacity mechanisms (CM) [42].

As discussed below, most countries analyzed in this study arrange long-term electricity auctions with market players to attract new investments and satisfy future electricity demand. Although the market agreements reached under the auctions cannot be called capacity mechanisms, they are strategies seeking long-term adjustment of the country's respective electricity systems [43].

Only in a minority of the identified countries did we find CMs focused on promoting RE. Specifically in Brazil, Chile, Colombia, and Peru, the CMs have been based on price and have now moved to mechanisms focused on quantity [44]. In Brazil, RE auctions are based on capacity, with contracts being tendered for 20-30 years, as in Peru and Colombia in their latest auctions. In addition to the mentioned countries, in Guatemala, the support through bids for RE works in parallel with auctions of conventional sources or direct payments. In these cases, the revenues that can be obtained in the auctions for the REs often represent both support for the REs and compensation for capacity, as well as further progress with the promotion of the technology mix, which can be managed centrally by facilitating the participation of different shares of diverse technologies [45].

The mechanisms identified for Chile and Peru can be defined as direct payments for capacity. Still, in the case of Brazil and Colombia, they could be described respectively as CM based on auctions and obligations [46].

For its part, Mexico has taken a different route developing a market for RE certificates called CEL (Certificados de Energía Limpia in Spanish), which requires increasing every year the RE share that can also participate in the capacity payment scheme to electricity generation companies, this approach has also been addressed by Chile [45], [47].

It is essential for the sustainable development of the electricity system the coordination of CMs with the support of the REs, either with a centralized approach with systems based on auctions or balanced by market conditions. Uncoordination in the different policies could counteract their positive effects and fight each other, causing an inefficient and

unsustainable system where the same RE share may generate the need to increase the share of electricity generation from conventional sources [45].

In these countries, although long-term auctions and other support schemes for REs are developed separately, according to some experts, the adverse effects of CMs are avoidable, which could be through the implementation of a standard model for all CMs in each country or the introduction of a single regional CM [45], [48]. This could be the solution after overcoming another political and international relationship obstacle [44].

2.3 Policies review

The institutional framework of renewable energy policy in Latin America is diverse, with many edges, and so is the sector it seeks to regulate. The first study on official national public agencies for renewable energy in Latin America conducted by IRENA in 2015-2016 [49] found that at least 120 public agencies are working on different aspects of renewable energy, from regulation and research to innovation and financing. Within the public institutions operating in the RE sector, they can be differentiated depending on their original mission. Some organizations were established with a non-renewable mission and burdened with responsibility for RE, either for historical reasons or because RE is part of the energy future. These include, for example, regulators responsible for the financing and pricing of all types of energy, mining organizations that regulate geothermal energy, development funds, and public banks. Likewise, some organizations have been created specifically for the RE sector. These include, for example, an RE fund, a specialized research center, a ministry, or RE departments within a ministry. However, most of the organizations surveyed by IRENA had energy-related commitments in their original mission, and, as RE became more important, these evolved to include more RE. These organizations vary from energy ministries and departments that develop and regulate ER policies to transportation system operators and state-owned oil and gas companies that distribute biofuels or rural electrification funds that use solar PV [23][22].

Within the RE organizations, one can differentiate between those dedicated to policy formulation and implementation; industry regulation (electricity, biofuels, environment, Etc.); planning; consulting and coordination; education, research, and development; energy access, technical standards, and regulations; tariff, tax and subsidy determination; financing; development projects; system operator and public energy companies.

Depending on the context of each country, its needs, capacities, and institutional development, responsibilities can be assigned to several organizations (e.g., Brazil, Colombia, and Mexico, with more than ten organizations identified in the IRENA survey) or concentrated in a few organizations (as in Costa Rica). The allocation of responsibilities is not necessarily clearly defined; there is often regulatory overlap, as in the case of biofuels involving energy, agriculture, and trade organizations, or geothermal within the energy, mining, and water organizations. Formal and informal coordination mechanisms are often undertaken by industry or private associations.

As REs grow over time, the number of institutions involved and necessary for this process will grow similarly. In a way, the increase of RE institutions represents a greater dynamism of the sector and the importance of the public sector in the development of RE in the region. With a regulatory framework for electricity and other relevant sectors and a developed institutional structure, the nature of renewable energy policies and the level at which they are approved is becoming more oriented. RE regulation, general or specific to a technology or resource, provides a tangible framework and ideal conditions for developing RE sources.

In general, there are two common conceptual perspectives on the energy sector in the region, one towards greater state control and the other towards greater private sector participation. Together with a culture of policy innovation, these perspectives have resulted in a variety of RE policies that encourage the use of RE from one or more energy sources. Analyzing the regulatory framework notes the crucial role RE policies play in disseminating. In the current context, it is even more special accelerated implementation and rapidly declining costs; the RE policy scenario is promoted by a political commitment, with more significant progress and diversity [22].

About 167 policies supporting renewable energies were identified in the countries reviewed, Figure 4 shows the mechanisms grouped by type and their percentage (%) in the region. Fiscal incentives, regulatory instruments, and financial mechanisms are widespread policies to promote renewable energy sources, identified in most countries and across sectors. These countries' most common power sector policies include auctions, with over 18 renewable energy auctions in Latin America, including all the countries from this study, and grid access policies, identified in 6 countries [22]. For heating purposes, a small but growing number of countries are adopting solar thermal mandates. Furthermore, renewable energy use in industry is growing, notably thanks to suitable contractual arrangements,

removing price distortions, and green labeling, which can open new market opportunities. The tables below summarize all the policies identified in the countries reviewed.

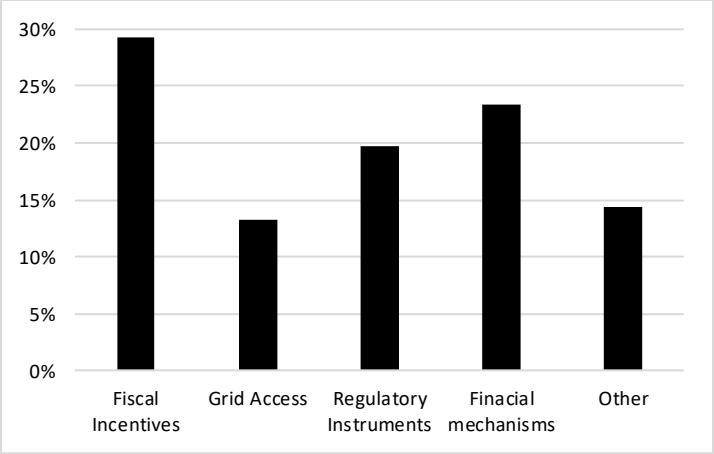

Figure 4: Percentage (%) of each RE policy type identified in Latin America

National policies (Table 2) are developed to articulate how governments seek to address energy development issues, including production, distribution, consumption, transition, and targets. Within this broad policy framework, more specific strategy documents and action plans usually indicate how the policy will be implemented within various energy sub-sectors.

The existence of renewable energy laws that provide a legal framework for promoting renewable energies, in general, indicates the country's support for renewable energies. Currently, within the countries reviewed, Argentina, Chile, Colombia, Dominican Republic, Honduras, Mexico, Panama, and Peru have renewable energy laws. However, it should be noted that the lack of such specific legislation does not necessarily mean the absence of strong support for renewables, with Brazil and Costa Rica as clear examples. Most Latin American countries, including Brazil, Costa Rica, El Salvador, and Guatemala, have one or more specific laws depending on the renewable resource in function (e.g., a geothermal or biomass law).

Table 2: Renewable energy policies in Latin America – National policies

Country	Renewable Energy Target	Renewable Energy Law / Strategy	Solar Heating Law / Programme	Solar Power Law / Programme	Wind Power Law / Programme	Geothermal Law / Programme	Biomass Law / Programme
Argentina	X	X	-	-	X	-	-
Brazil	X	-	-	-	X	-	-
Chile	X	X	X	X	-	X	X
Colombia	X	X	-	-	-	-	-
Costa Rica	X	-	-	-	-	X	X
Dominican Republic	X	X	-	-	-	-	-
El Salvador	X	-	-	X	-	-	-
Guatemala	X	-	-	-	-	-	X
Honduras	X	X	-	-	-	-	-
Mexico	X	X	X	-	-	X	X
Panama	X	X	X	X	X	-	X
Peru	X	X		X	-	X	-

X Active **SL** Subnational level **UD** Under development

Source: Adapted from [22] and EIA data

Auctions and **fiscal incentives** (**Table 3**) are the most widespread support mechanisms in the electricity sector. Fiscal incentives include tax exemptions, accelerated depreciation, import, and other benefits, such as tax stability. Tax exemptions can include income tax, VAT, sales tax, wealth tax, resource tax, local taxes, administrative fees, import duties, and other fees. Exemptions may take the form of reducing or eliminating taxes, refunds,

deductions, tax credits, or different payment schedules. Tax exemptions generally apply to services and equipment and pre-investment expenditures related to renewable energy projects, as well as revenues from the sale of electricity and, in some cases, carbon credits and other ancillary revenues.

Table 3: Renewable energy policies in Latin America – Fiscal Incentives

Country	VAT Exemption	Fuel Tax Exemption	Income Tax Exemption	Import / Export Fiscal Benefit	National Exemption of Carbon Tax	Accelerated Depreciation	Other Fiscal Benefits
Argentina	X	X	X	X	X	-	X	X
Brazil	-	X	-	X	X	-	-	X
Chile	-	X	-	-	-	X	-	X
Colombia	X	X	X	X	-	X	X	X
Costa Rica	-	-	-	X	-	-	-	X
Dominican Republic	X	X	X	-	-	-	-	X
El Salvador	-	-	X	X	-	-	-	-
Guatemala	X	-	X	X	-	-	-	X
Honduras	-	-	X	X	-	-	-	X
Mexico	-	-	-	-	X	X	X	-
Panama	X	X	X	X	X	-	X	X
Peru	X	-	-	-	-	-	X	X

X Active **SL** Subnational level **UD** Under development

Source: Adapted from [22] and EIA data

As mentioned above, grid access (Table 4) policies are one of the most common policies in the region. These are essential components for deploying renewable energy technologies, which are otherwise often unable to reach the market due to technical and commercial barriers. These include mandated grid access, discounts and exemptions from transmission fees, preferential dispatch, priority or dedicated transmission, and planning considerations.

Table 4: Renewable energy policies in Latin America – Grid Acces

Country	Transmission Discount / Exemption	Priority / Dedicated Transmission	Grid Access	Preferential Dispatch	Other Grid Benefits
Argentina	-	-	-	-	-
Brazil	X	-	-	-	-
Chile	X	-	X	-	-
Colombia	-	-	-	-	X
Costa Rica	-	-	-	-	-
Dominican Republic	X	-	-	X	-
El Salvador	-	-	X	X	-
Guatemala	X	-	X	-	-
Honduras	X	UD	X	-	-
Mexico	X	X	X	-	X
Panama	X	-	-	-	X
Peru	-	X	X	X	X

X Active **SL** Subnational level **UD** Under development

Source: Adapted from [22] and EIA data

The consolidation of renewable energy policies in the region, with effective use of **regulatory instruments (Table 5)** ranging from auctions for renewable generation to blending mandates for solar or other technologies, combined with rapid reductions in technology costs, are among the factors contributing strongly to these investment levels. The region's most common power sector policies include auctions, which we will review in more detail below. Other rapidly growing policies are net metering and self-consumption, which have been developing in all the countries reviewed. These policies allow consumers to generate their electricity from renewable energy sources and contribute an extra injection of energy to the overall grid, either to offset future consumption or to receive remuneration based on contractual terms. Specific design elements include, among other things, connection guidelines, remuneration terms, banking, compensation terms, off-site generation, transmission fees and losses, and taxation.

Table 5: Renewable energy policies in Latin America – Regulatory Instruments

Country	Auctions	Feed-in Tariff	Premium	Quota	Certificate System	Net Metering	Solar Mandate
Argentina	X	UD	-	-	-	-	-
Brazil	X	UD	-	-	-	X	**SL**
Chile	X	-	-	X	X	X	-
Colombia	X	-	-	-	-	X	-
Costa Rica	X	-	-	-	-	X	-
Dominican Republic	UD	-	-	-	-	X	-
El Salvador	X	-	-	-	-	X	-
Guatemala	X	-	-	-	-	X	-

Honduras	X	-	X	-	-	X	-
Mexico	X	-	-	X	X	X	**SL**
Panama	X	-	X	-	-	X	X
Peru	X	X	X	X	-	-	-

X Active **SL** Subnational level **UD** Under development

Source: Adapted from [22] and EIA data

Access to financing is crucial for developing renewable energy resources, especially considering the higher initial cost of some technologies compared to their conventional alternatives. In general, all countries have set up public funds or public **financial mechanisms (Table 6)** to promote renewable energy projects that meet specific criteria in each country.

Table 6: Renewable energy policies in Latin America – Financial Mechanism

Country	Currency Hedging	Dedicated Fund	Eligible Fund	Guarantees	Pre-investment Support	Direct Funding
Argentina	X	**SL**	-	-	X	**SL**
Brazil	-	X	X	-	X	X
Chile	-		-	-	X	X
Colombia	-	X	X	-	-	-
Costa Rica	-	-	-		X	-
Dominican Republic	-	-	-	-	X	-

El Salvador	X	X	X	X	X	-
Guatemala	X	-	X	X	-	-
Honduras	X	X	-	X	X	-
Mexico	-	X	X	-	X	X
Panama	X	X	-	X	-	X
Peru	X	-	X	-	-	X

X Active **SL** Subnational level **UD** Under development

Source: Adapted from [22] and EIA data

Other policies (**Table 7**) focused on rural electrification strategies in the region, increasingly evident the vital role of off-grid renewables; all countries reviewed having included renewable energy technologies in policies, programs, and projects for energy access. Among the most popular policy instruments are concessions to provide energy access through solar home systems. The concessions can be awarded via direct contract, as in Argentina, or through auctions, as in Peru.

Table 7: Renewable energy policies in Latin America – Other Policies

Country	Renewable Energy in Social Housing	Renewable Energy in Rural Access Programmes	Local Content Requirements	Special Environmental Regulations	Social Requirements
Argentina	-	X	-	-	-
Brazil	X	X	X	X	-
Chile	-	X	-	-	-
Colombia	-	X	-	**SL**	X

Costa Rica	-	X	-	-	-
Dominican Republic	-	X	-	-	-
El Salvador	-	X	-	X	X
Guatemala	-	X	-	-	-
Honduras	-	X	X	-	-
Mexico	X	X	-	-	X
Panama	-	X	X	-	-
Peru	X	X	-	-	-

X Active **SL** Subnational level **UD** Under development

Source: Adapted from [22] and EIA data

Auctions

Although there are political and regulatory differences in each country, applying auctions to purchase long-term contracts with independent power producers is a standard instrument in the region to increase private investment and the deployment of renewable capacity. It has been adopted by most countries reviewed between 2005 and 2019, including the largest economies in the region, such as Brazil being a pioneer in the process.

The great attraction of auctions is their ability to obtain transparent prices because they can be adapted to different market designs and applied both for a particular technology and for technology neutrality. Various technologies beyond wind and solar appear in auctions in Latin America, thanks to the availability of biomass and hydropower (see ***Table 8***). Several countries in Central America, like Honduras, held auctions before 2010 but have suspended their programs in recent years.

In 2016, auctions held in Brazil, Peru, and Panama were specific (or have a specific contract) for each renewable technology (wind, PV, small hydro, biomass). Chile and Mexico use technology-neutral auctions, while Colombia has renewable energy auctions

(for a group of technologies). Technology-specific auctions have the advantage of planning supply diversification, and neutral auctions have the advantage of increasing competition and reducing costs [50].

In the results of a review made by IRENA 2019 [47], it is noted how the RES competitiveness has improved and how they contribute to the RES targets of each country. In 2017, the Argentine government awarded 2,042 MW projects under Round 2 of the RenovAr program. The awards included 993 MW of wind capacity at an average price of USD 41/MWh and 816 MW of solar at an average price of USD 43/MWh, as well as 143 MW of biomass at an average price of USD 107.5/MWh, 69 MW of biogas at an average price of USD 153/MWh, and 21 MW of small hydro at an average price of USD 98.9/MWh.

In four auctions held between 2017 and 2018 in Brazil, 2,828 MW of wind capacity, 1,823 MW of solar, 650 MW of small hydro, and 292 MW of biomass were awarded. The technology-neutral auction in 2017 was dominated by solar PV (791 MW out of the total capacity assigned, 64 MW to wind, 25 MW to biomass, and 12 MW to hydro). In the technology-neutral auction in October 2019, only 530 MW of the 2.98 GW of capacity contracted was awarded to solar, at an average price of USD 20.52/MWh, more than 1 GW was awarded to wind, 734 MW went to gas-fired power, 445 MW to hydro and 229 MW to biomass.

Chile's technology-neutral auction, held in November 2017, awarded 2,200 GWh, equivalent to approximately 600 MW of renewable capacity (equivalent to the estimated annual energy demand). The final award price was USD 32.5/MWh.

In October 2019, Colombia awarded 1.3 GW of solar and wind energy following the cancellation of the first renewable energy auction in February. The average price for the eight signed contracts (5 wind and three solars) was COP 95,650/MWh (USD 28/MWh). In 2021, the third auction was executed, assigning contracts to 11 solar generation projects with an installed capacity of 796.3 MW and a weighted average price of COP 135,850/MWh (USD 39.76/MWh) [51]. In January 2017, El Salvador awarded 50 MW of wind at an average price of USD 98.78/MWh and 120 MW of solar capacity at an average price of USD 49.55/MWh.

Table 8: RES Auctions through 2021

Year	Country	Technology
2007-2008	Brazil	Biomass, hydro
	Argentina	Wind, solar, biomass, hydro
2009	Brazil	Wind
	Peru	Wind, solar, biomass, hydro
	Brasil	Wind, biomass, hydro
2010	Honduras	Wind, biomass, hydro
	Peru	Solar, biomass, hydro
	Brazil	Wind, biomass, hydro
	Guatemala	Hydro
2011	Panama	Wind
	Peru	Wind, solar, biomass, hydro
	Brazil	Wind, biomass, hydro
	Costa Rica	Wind, hydro
2012	Guatemala	Wind, solar, biomass, hydro
	Panama	Hydro
	Brazil	Wind, solar, biomass, hydro
	El Salvador	Wind, solar, biomass, hydro
2013	Guatemala	Wind, solar, biomass, hydro
	Panama	Wind, hydro, solar
	Peru	Hydro
2014	Brazil	Wind, solar, biomass, hydro
	Brazil	Wind, solar, biomass, hydro
2015	Guatemala	Hydro

2016	Argentina	Wind, solar, biomass, hydro
	Brazil	Wind, biomass, hydro
	Chile	Neutral
	El Salvador	Wind, solar
	Mexico	Wind, solar
	Peru	Wind, solar, biomass, hydro
2017	Argentina	Wind, solar, biomass, hydro
	Brazil	Wind, solar, biomass, hydro
	Chile	Neutral
	El Salvador	Solar
	Mexico	Solar
2018	Argentina	Wind, solar, biomass, hydro
	Brazil	Wind, solar, biomass, hydro
	Mexico	Wind, solar
2019	Argentina	Wind, solar, biomass, hydro
	Brazil	Wind, solar, biomass, hydro
	Chile	Neutral
	Colombia	Wind, solar
2021	Colombia	Solar

Source: Adapted from [47], [50], [52]

Auctions can be used to purchase power from existing plants or new plants still in the design stage and are a powerful mechanism to ensure long-term resource adequacy, especially in the case of markets with significant renewable energy participation, such as intermittency, seasonality, and low operating cost make developers particularly averse to relying on the spot market. Therefore, using auctions to match independent power producers with long-term buyers at set prices reduces risk, improves financing, and enables significant long-

term investments. Long-term PPAs can provide revenue stability and protect investors from the effects of changes in regulation or market design [50].

Because market failures can affect new and existing plants, procurement auctions for long-term contracts can allow competition from existing plants and new projects on a level playing field. This approach is used in Chile, Colombia, Mexico, Panama, and Peru.

Targets for renewable energy sources

Considering the commitments in the Paris Agreement, these days, it is of utmost importance to set renewable energy targets in the policy framework, which manifests the government's long-term commitment. The ambition and vision of Latin American countries to develop renewable energies have been translated into renewable energy targets, providing a trajectory of development of renewable energies and a long-term government commitment to renewables and the timetable planned by governments [22].

Table *9* is summarized the targets that have been identified in the countries reviewed. **Figure 5** shows the relationship between the installed RE capacity in 2020 with the dark gray column, the target capacity defined by the authorities in each country with the light gray column, and the forecast electricity demand for the target date represented by the black column. The difference between the light gray and black columns represents the future demand to be covered by fossil fuels. The ambition of renewable energy targets varies widely across the region, in line with country conditions, investment frameworks, and enabling policies. Some countries are on track to or are already exceeding their targets. Chile and Costa Rica, for example, have made remarkable progress in the past decade thanks to clear political commitment and a favorable policy and investment climate. However, if hydropower is excluded, most Latin American countries have relatively little installed renewable energy capacity. While hydropower has zero emissions, it has other undesirable impacts, particularly "large" hydropower, where dams have a significant environmental impact. "Small" hydropower has a lower environmental impact but is more vulnerable to climate change, given the variation in rainfall. The relatively slow adoption rate of photovoltaic and wind power makes it difficult to achieve electricity generation targets [24].

Table 9: Targets for renewable energy sources by country.

Country	RES targets
Argentina	10,000 MW of (potential) renewable energy by 2025. 20% of national electricity consumption by 2025, supported by Law 27,191.
Brazil	Increase wind power share to 11.84% in 2024 (from 9.12% in 2019) 24.9% of electricity generation from wind and solar resources by 2024
Chile	20% of the Electricity Generation from renewable sources by 2025 (not considering hydropower larger than 20 MW). 45% of the new capacity by 2025.
Colombia	At least 60% of the electricity generation from renewable sources by 2035 and 70% by 2050. 15% of the energy park is based on non-conventional renewable energy by 2029.
Costa Rica	98% of electricity generation by 2035 (74% hydropower, 15% geothermal, 9% wind-biomass-solar)
Dominican Republic	15% of electricity generation by 2024 (6% wind, 8% solar, 1% biomass)
El Salvador	Additional capacity by 2026 compared to 2012: 60 MW wind, 90 MW solar PV, 200 MW solar thermal, 60-89 MW geothermal, 162.7 MW small hydro (<20 MW), 45 MW biomass, and 35 MW biogas
Guatemala	64% of electricity generated by 2030
Honduras	Renewables will supply 60% of energy demand by 2022 80% of electricity generation by 2034
Mexico	Clean energy share of total electricity generation: 30% by 2021, 35% by 2024

Panama	Install an additional 706.3 MW of hydropower between 2009 and 2023
Peru	18.4% of electricity from renewables by 2030 5% of electricity generation by 2021 (excluding hydropower). 20% of electricity generation by 2025 (including hydropower < 20 MW).

Source: Argentina [53], [54], Brazil [55], Chile [56], [57], Colombia [58], Costa Rica [59], Dominican Republic [60], El Salvador [61], Guatemala [62], Honduras [49], Mexico [63], Panama [64], Peru [65].

As shown in **Table *9***, most renewable energy targets and strategies in Latin America are stipulated in five- or ten-year electricity expansion plans or integrated resource plans (e.g., Brazil, Mexico). However, as a region, Latin America does not have a coordinated energy policy as, for example, the EU currently does [24]. Implementing a direct regional policy to promote the transition to renewable sources makes it more challenging. This difficulty can be seen in the target dates for achieving RE objectives. In contrast, it is possible to find policies and targets with a higher standard for the transition, for example, Honduras or El Salvador, and other countries with relatively low targets, such as Colombia or Peru (concerning renewables).

Furthermore, in several Latin American countries, the targets do not always distinguish between hydropower and other non-conventional renewable energy sources, such as solar and wind. However, the targets focus solely on promoting wind and photovoltaic generation. As discussed above, the current share of renewables (excluding hydropower) is relatively low in most Latin countries, for example, in the case of Colombia, where photovoltaic and wind generation are considered pilot projects.

Latin American countries have included their renewable energy targets in their NDCs. For example, Brazil's NDC sets a non-hydro renewable electricity supply target of 23% by 2030, up from 9.3% in 2014 [66]. To be seen as credible by investors and provide a clear trajectory for the future evolution of the energy matrix, renewable energy targets need to be translated into specific policies and measures. The implementation of these policies points to the

importance of institutions and how their design is tailored to specific countries and market conditions.

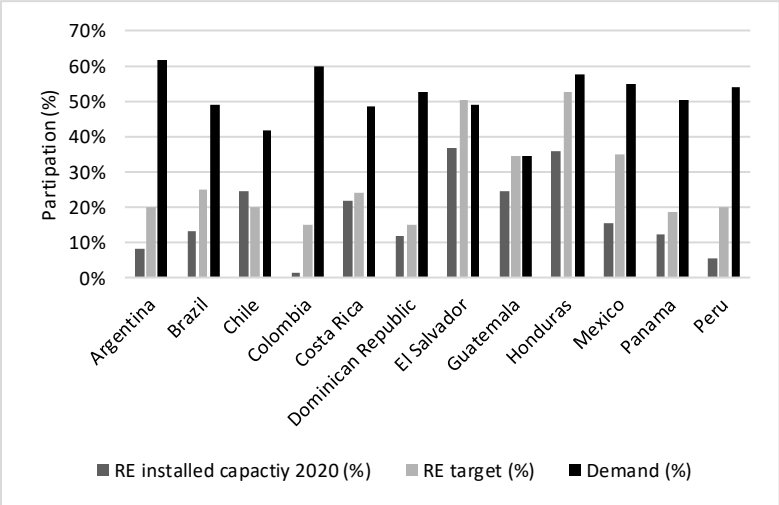

Figure 5*:* Demand satisfied with the installed capacity (IC) of Renewable Energy (RE) target by country.

Most countries are still on track to meet their RE target; however, countries such as Colombia and Peru are still far from meeting their goals. Colombia is expected to make good progress in the coming years, considering the success of its latest green energy auctions. Argentina has not performed well and has been impacted by a low investment over the last few years [22].

Costa Rica has made satisfactory progress in diversifying its matrix and using complementary renewable sources, such as wind and hydroelectric. Its RE policy framework combines specific technology auctions, fiscal incentives, and tax incentives for using renewable energy sources.

The progress on the results of the RE targets is a sample of a solid and structured regulatory framework; this reduces investment uncertainty because it provides a clear trajectory for the future evolution of the energy system, so each country should implement its RE targets in concrete policies and measures.

2.4 Green power markets

FiTs, renewable portfolio standards (RPS), and other certificate systems are the most common and far-reaching renewable energy policies used worldwide. FITs and RPSs aim to create markets for renewables and thus represent an attempt to include renewables as a long-term component of a jurisdiction's electricity portfolio. FITs and RPSs have been widely used to promote renewables at the national and sub-national levels. International donors, NGOs, and companies have actively encouraged developing countries to adopt these policies [67]. However, these policies have had limited success in Latin America.

Argentina and Brazil each established FiTs, which are no longer active. Several of the FiT policies in Latin American countries resulted in limited renewable energy development, either because their levels were set too low (Argentina), because of the absence of official regulation to enforce the laws, or, more often, because there was no adequate legal environment (e.g., lack of clarity of interconnection rules, lack of interconnection rules, lack of standard contracts for IPPs, Etc.). Honduras and Nicaragua have limited but practical implementation of FiTs, and Peru uses FiT design elements in its auction system [49].

An alternative green power product to FITs identified in Latin America and now with increased market acceptance in the region are the EACs. This is a general term for official certification of renewable energy consumption. Each EAC typically represents proof that 1 MWh of renewable energy has been produced and added to the grid. Currently, different certification and traceability mechanisms are involved in the region, as seen in **Figure 1**.

The EACs directly promote renewable energies and are mainly characterized by the existence of a legal imposition by a state or by the voluntary participation of market agents. Within a regulated market, it is generally established that a certain percentage or quota of electricity generated, supplied, or consumed (a percentage that is generally fixed increasingly over time) has its origin in RES. In these cases, the state intervenes as the system regulator, those subjects obliged to reach a certain quota or percentage must prove their compliance by obtaining and submitting to the competent authority an EAC [68].

On the other hand, the voluntary market is developed by initiatives such as RE100 or CDP, which bring together the most influential companies in the world committed to 100%

renewable electricity, seeking to mitigate climate change by offsetting their emissions and accelerating the energy transition [69].

So far, in Latin America, only Chile has a system of renewable energy certificates. In contrast, Mexico has a "clean energy system," also oriented to the possibility of exporting clean energy to the United States (where certificate systems predominate); in the short term, it does not seem that EACs will play an essential role in policies to promote renewable electricity in Latin America[22].

Best practice around the world is to use EAC that is based on robust energy tracking and auditing systems that establish a link between the production of energy at a given source (with its specific attributes) and its sale through a network of suppliers, all the way to the end consumer who will claim the specific characteristics of the source. This tracking system does not intend to follow the physical flow of electricity in the grid (which is not feasible). Instead, it aims to track the contractual relationships of the purchase of electricity in a robust and auditable way. Such systems provide the ability to document and track the entire chain of custody and have already been implemented for carbon markets, forest products, marine products, and the electricity market [70]. For electricity markets in Latin America, we found four prominent established systems, the International REC Standard (IREC), Tradable Instruments for Global Renewables (TIGR), EcoGox, and Clean Energy Certificates (CELs). **Figure *6*** shows the portion of installed RES capacity by the country that has been certified under an EAC.

The **IREC** provides the blueprints for a standardized tracking system that can be easily implemented in any country or region. Together with governments, policymakers, and informed stakeholders, the IREC provides a simple method for the voluntary or compliance implementation of a tracking system, depending upon the needs of the local authorities. For this reason, the legislative basis for IREC certificate issuance differs in each country where an IREC standardized tracking system is active. This is the most common EAC in Latin America and the one with the largest share of installed RE capacity in each country, as can be seen particularly in Chile and Panama (see **Figure *6***).

In **Argentina**, although no projects have been registered under IREC to date, under the World Bank's Market Readiness Partnership (PMR), the Argentine Government is developing policies to support the achievement of NDCs (Nationally Determined Contributions). The proposal that most directly addresses the need to increase the use of

RE is the Renewable Energy Certificate (REC) System. However, implementing a mandatory REC scheme to support the current regulations has been complex [71].

Brazil has had significant developments in I-REC and substantial growth in interest from power generators and trading groups. With over 12,000 MW registered mainly from hydro (64%), followed by wind (22%).

In the last decade, **Chile** has taken advantage of other local resources, such as gusty coastal winds, intense desert sun, and plate tectonic conditions, making geothermal power generation viable in some areas. This is also reflected in the amount of registered MW that exceeds 2,000 and with significant participation of solar plants (42%). Chile represents an excellent opportunity for EACs with a solid regulatory framework, defined by several effective policies and relative overall economic stability. It also has a more extensive clean energy component manufacturing value chain than many other developing countries [72].

Due to the climatic conditions and the geographical position of **Colombia**, it has significant resources for developing RE projects. However, there are still different challenges to the stability of an EACs market. Although Law 1715 was passed in 2014, the regulation of incentives and tax exemptions is still in process. The law also lacks perspective regulation for self-generation and the sale of self-generated electricity. The concentration of RE resources in Colombia's ZINs is problematic because delivering the generated electricity to the national grid would be complicated. Another critical barrier to deploying existing RE has been the high capital cost associated with such technologies, mainly because they have to be imported. In addition to high investment costs, generating electricity from some RE technologies is higher than existing market prices, for example, in some biomass projects [73]. Despite this, Colombia has been an active market in the region with over 2,000 MW registered with IREC, mainly hydroelectric moreover, there are recently the **EcoGox** EACs, which were developed by the Colombian market operator XM for the electricity sector of any country under the voluntary market. This mechanism has adopted international best practices for renewable energy certification programs and, in 2021, had more projects registered than IRECs. EcoGox differs from other certification mechanisms in that it certifies

units in kWh and not MWh, thus allowing participation in the market for regulated users and not necessarily linked to the wholesale market [74].

The **Costa Rican** electricity sector is highly exposed to regulatory interference risk, given the lack of clear and transparent electricity tariff schedules. The proposal to incorporate the I-REC Standard was adopted by the Vice Minister of Energy and Environment with the purpose that I-REC begins to operate on a voluntary basis because it will help to position the country as a place to manufacture near-zero carbon products or processes [75]. By 2021, 23 MW will have been registered as 100% wind power.

Like Argentina, no projects have been registered in the **Dominican Republic**, so there is not yet an EAC market. Dominican Republic market players need assurances on a stable regulatory framework and better coordination between government entities. For example, in 2016, Law 57-07 was amended to change tax incentives, so the percentage of investment eligible for tax credits was reduced from 75% to 40% [76].

El Salvador has sought to establish a regulated system of EACs, the electricity markets have been promoting I-RECs with different sector institutions such as SIGET and the CNE [77], and so far, a voluntary market continues with 100 MW of registered solar.

Despite the problems of RE investment in **Guatem**ala, Article 6 of Decree 52-2003 made some progress in regulating the ownership and economic benefit of RECs as the exclusive right of the power generators [78]. In addition to more than 300 MW registered in IREC in Guatemala, we also found the registration of 19 MW of TIGRs. In 2016 the **TIGRs** was launched by APX, the company that operates the tracking systems in the United States, to meet the demand for energy attribute tracking in Asia and beyond [70].

In **Honduras**, only 130 MW registered in IREC were identified; however, many small hydropower plants are expected to participate [79].

In addition to IREC, the **CELs** in **Mexico** were introduced as a mechanism for tracking renewable electricity and promoting investment in clean energy technologies. CELs are issued by the Energy Regulatory Commission (CRE) and redeemed by participants who claim the number of certificates which reflects the amount they have purchased from the electricity market [80]. The CELs could be bundled together with energy and capacity products. Auctions for certificates in such a context can guarantee long-term certainty concerning production and prices, mitigating risk for generators and obliged parties [22].

The issuance of IRECs is limited in Mexico to avoid the risk of double counting; therefore, a large part of RE projects are registered in CELs [80].

Even though **Panama** favors conventional sources in fiscal incentives [81], we found that 22% of its installed RE capacity is registered in IREC. We observed more of a voluntary commitment from market agents than from the government itself.

The **Peruvian** government has traditionally favored the exploitation of the country's abundant natural gas reserves, while RES generators receive less favorable tax incentives. The General Directorate approved the I-REC system of Energy Efficiency of the Ministry of Mines and Energy as a voluntary mechanism that would position the country at the same level as others, such as Chile and Colombia [82]. So far, the registration of projects in IREC does not reach 1% of installed RE capacity.

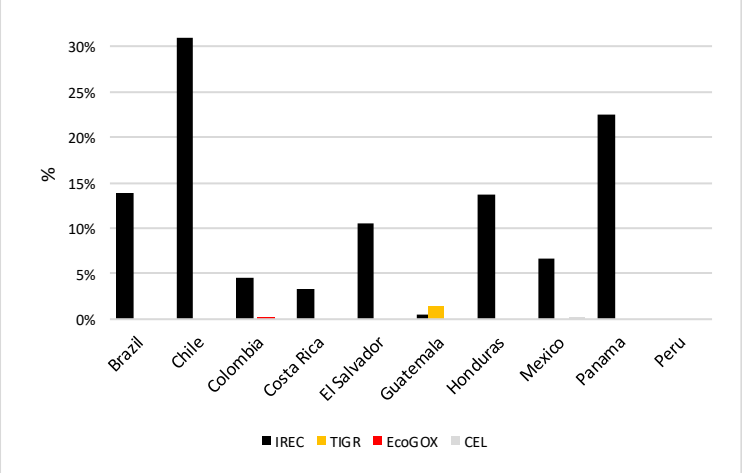

Figure 6: Scope of EACs on RES capacity in Latam. Sources: Author based on IREC, TIGR, EcoGox, and CEL.

Reviewing the voluntary or mandatory markets that exist in the region, there is not a unified "market price" handled by each EAC. Most operations are carried out through individual bilateral agreements, so it would be necessary to approach the registered/public market agents. These entities participate in the market daily and are, therefore, aware of price statistics, generally confidential information. However, we know that prices can vary significantly based on the origin of the certificates (location, age, device, technology, size, grant support, sustainability labels, and more). Therefore, there is no single price for EACs,

as is common in more fungible markets, such as carbon. In addition, the registry mechanisms have fees for registration and issuance of certificates, so the price must also exceed this cost [83]. Attribute tracking has become an integral part of electricity market development. The standardization of EACs will enhance competition, playing a pivotal role in ensuring that both power generators and end users have access to credible, transparent, and globally harmonized information on the origin of their electricity. EACs are also becoming the standard denomination instrument for other energy markets beyond electricity, such as hydrogen.

On the other hand, through the demand for EACs, we know that the price of electricity is essential for the certified volume. The price of green (certified) electricity is finally given by both the certificate and wholesale price of electricity. End users desiring green power must purchase Physical Electricity and EAC. Therefore, it can be thought that increases in the price of electricity raise the final costs of green electricity for end users, decreasing the demand for EAC in a purely voluntary market [84]. This decreases the interest of lower electricity consumption agents that do not have any voluntary commitment, causing an oversupply of EACs since most generators certify a large part of their energy, consequently decreasing the market value. Hence, its impact as a mechanism for RE promotion loses importance.

3. Conclusions and policy implications

Las Latin American countries have increased their ambition for the RE share of their electricity matrix to meet their 2030 targets, so climate change awareness has prompted a re-evaluation of energy policies. In this manuscript, we have reviewed a number of countries that tried to promote the transition from fossil fuels to renewable sources by developing different energy/climate plans, strategies, and policies. In some countries, these strategies have produced results in increasing their share of RE, such as Costa Rica, Honduras, and Guatemala; however, the installed capacity of RE is still poorly representative.

The reality of Latin America's electricity matrix is not aligned with the policies promoted by the governments. The increase in the use of fossil fuels is more significant concerning hydropower and RE, as evidenced in the document. It is necessary to improve efforts in developing the policy framework, integrating different and complementary capacity mechanisms, and increasing the number of incentives that stimulate investment in RE. If this does not occur, several Latin American countries will likely not achieve their proposed goals under the Paris Agreement.

Even though governments have so far made efforts to promote the RE share and we have noted an increase in RE penetration in recent years, it is important to emphasize that there is still a general growing trend in most countries regarding the use of thermal resources in power generation, an issue that goes ignored in many political discussions and requires important attention.

The EACs are adapted to the new electricity markets as an interesting complementary mechanism for RE promotion; however, it is necessary to standardize and regulate them; these are emerging markets, especially in Latin America. It is necessary to have regulation that allows competition and incentives that stimulate demand, such as renewable energy consumption auctions, similar to the case in Mexico, or integration with fiscal benefits. It is

also necessary to increase local education on these new mechanisms, many market agents and politicians are unaware of these new alternatives, so it is of utmost importance to develop other research in the region that evaluates the integration of EACs with other energy/climate policy mechanisms, such as the carbon tax in Colombia or Emissions Trading System (ETS) coming down the pipeline.

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