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Attaining the Energy Sustainability: Analysis of the Ecuadorian Strategy

Ku zrównoważoności energetycznej: analiza Strategii Ekwadorskiej

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Abstract
The exploitation of renewable energy sources is a tactic adopted by several states around the globe to achieve a sustainable development. Many countries are looking forward the integration of this type of energy into the traditional power system by the beginning of the next decade to reduce the greenhouse gases emission and consequently lessen their effect in the climate change. However, this integration involves studies at technical, environmental and political levels. This article aims at identifying and assessing the level of incorporation and performance of the alternatives clean methods for generating electricity into the national energy system. It presents a quantitative analysis of historic data to better understand the gradual insertion of renewable sources to the electric energy production. This study also comprises a qualitative analysis of the projects executed so far by the Ecuadorian Government to accomplish the compliance with the long-term policies defined in the Master Plan of Electrification 2013-2022 released by the Ministry of Electricity and Renewable Energy in 2013. The outcomes of this research shows that the measure taken in the last sixteen years by the administration are aligned with the guidelines stated in the strategic planning proposed for the decade from 2013 to 2022.

Key words: Ecuador, capacity analysis, energy supply, renewable resources, sustainable development

Streszczenie
Wykorzystywanie odnawialnych źródeł energii stanowi to istotna część strategii rozwoju zrównoważonego. Wiele krajów zamierza w ciągu najbliższej dekady zintegrować te typy energii z konwencjonalnym systemem energetycznym, aby obniżyć poziom emisji gazów cieplarnianych, a poprzez to zredukować negatywny ich wpływ na klimat. Ta integracja obejmuje badania odnoszące się do aspektów technicznych, środowiskowych i politycznych. W niniejszym artykule oszacowano poziom włączenia i efektywności alternatywnych czystych metod produkcji energii elektrycznej w ramach krajowego systemu energetycznego. Dokonano ilościowej analizy danych historycznych, aby lepiej ukazać przebieg procesu wprowadzania odnawialnych źródeł energii do energetycznych systemów produkcyjnych. Przeprowadzono także analizę jakościową projektów wprowadzanych przez rząd Ekwadoru mających na celu osiągnięcie zgodności z długoterminowymi celami określonymi w Planie elektryfikacji na

lata 2013-2022, ogłoszonym przez ministra energetyki i odnawialnych źródeł energii w 2013 r. Przeprowadzone badania pokazują, że działania podjęte w ciągu ostatnich 16 lat przez administrację są zgodne z wytycznymi zawartymi w planowaniu strategicznym zaproponowanym na dekadę 2013-2022.

Słowa kluczowe: Ekwador, analiza wydajności, zaopatrzenie w energię, odnawialne źródła energii, zrównoważony rozwój

1. Introduction

Nowadays, there is no context in daily life where electricity is not used. The enhanced standards of life, the high dependency of technology and the unceasing increment of the world's population entails a growing demand for energy. The massive utilization of electricity and the progress that it implies have led to consider it one of the most important resource of the modern time (International Energy Agency, 2016). The demand for energy keeps increasing, whereas the nonrenewable sources keep diminishing, what has led to the global search for alternative energy systems that can fulfill the energy supply and demand (Day & Day, 2017). In addition, the widely-discussed effects of fossil fuels to the ecosystem, such as the weakening of the ozone layer, global warming, environment pollution, and health hazards to each living being (Gonenc & Scholtens, 2017) have caused the concern of international entities for cleaner energy production systems that preserve the biosphere but also guarantee energy security and economic feasibility.

The studies of Droege (2008) and Ruggiero and Lehkonen (2016) indicate that international regulation bodies agreed to exploit renewable sources to produce energy since they are ecofriendly and virtually endless, they are becoming economically-speaking more competitive, and they are experiencing a favorable political horizon.

Worldwide, several nations are adopting and promoting the usage of renewable energy (RE) resources and technologies (Hussain, Arif, & Aslam, 2017), including biofuel, biomass, geothermal energy, hydropower, solar energy, tidal power, wave power and wind power. This alternative sources allow achieve a real level of sustainability (Botelho, Pinto, Lourenço-Gomes, Valente, & Sousa, 2016; Chang et al., 2017), ensuring an optimal industrial production that boosts the economy, supporting the living standards as currently known, and caring about the conservation of the Earth's natural legacy.

According to the Renewable Energy Policy Network for the 21st Century – REN21, around the globe the fossil fuels are the most used resources to produce this vital utility (Kristin Seyboth et al., 2016). As of 2015, 76.3% of the total production of electricity came from non-renewables, while only a 23.7% was renewable electricity. The global final energy consumption is estimated to be arranged as 78.3% of fossil fuels, 19.2% of renewables and 2.5% of nuclear power. Per the International Renewable Energy Agency – IRENA, the total world capacity of renewable energies was 1964655 kW for the year 2015 (International Renewable Energy Agency, 2016).

Although Ecuador still depends on fossil fuels and has a big unexploded oil reserve, the Yasuni-ITT, it has a bigger ecologic and cultural heritage to protect (Vallejo, Burbano, Falconí, & Larrea, 2015). Since the national territory has abundance of natural resources, the government is betting at alternative sources to become independent of the exhaustible combustibles. The generation, employment and improvement of renewable energies in the country plays an important role in the new framework for the sustainable energy development planned by the current administration.

To cover the objectives set out, this paper starts with a background study that includes the analysis of the strategies and decisions applied in different countries to assess the level of sustainability and a brief review of the history of energy production in Ecuador since the year 2000. This information determined the methodology of the research comprising the replication of the procedures to evaluate the viability of renewables in the country as well as to examine the national historic energy data and indicate whether the inclusion of this alternative form of generation is feasible in the country or not. Then, the following section gives a summary of the national status of renewable generation and it carries out an analysis of the strategies for the energy sustainability proposed by the administration of this Latin American country. After that, and in order to complement the information learned so far, the next section quickly examines some impacts that the insertion of renewable energies into the National Integrated System (NIS) causes to the nation. Finally, it draws out some conclusions about the compliance with the Master Plan of Electrification 2013-2022.

2. Background

Before examining the data compilation on energy capacity of Ecuador and drawing an evaluation of its strategy for energy sustainability, it is imperative to learn the outcomes of different strategies and long-term policies applied by some countries to stimulate the investments in renewable energies, such as feed-in tariffs (FIT), net metering, auctions and shares. This researches are going to be reviewed and used as tools to assess the performance and conformity of the renewables in Ecuador.

Currently, the energy regulatory bodies are implementing FITs as a mean to subsidize the cost of energy to accomplish a successful deployment of renewable technologies, even though there are more economic opportunities in non-subsidized business environments. This measure is generally applied since the users are producing part of the energy. Studies carried out in Japan (Dong & Shimada, 2017), South Korea (Koo, 2017), the European Union (Pablo-Romero, Sánchez-Braza, Salvador-Ponce, & Sánchez-Labrador, 2017), India (Tomar & Tiwari, 2016), and the Latin America and the Caribbean Region (Jacobs et al., 2013) demonstrated that FITs are good approach to stimulate the deployment of RE systems. Other work regarding the effect of RE policies on economic growth in Middle East and North Africa countries revealed a positive influence (Kahia, Kadria, Ben Aissa, & Lanouar, 2017; Kahia, Safouane, Aïssa, & Lanouar, 2017).

The new European reference framework is set to evaluate the performance of the RE sources as well as to present the new objectives for the energy sector and the new guidelines to develop circular economy models. The study by D'Adamo and Rosa (2016) reviews this framework but it reveals that both the circular economy models and the objectives are not very reachable for many countries in the continent. It also recommends new target values and a performance assessment viable for each country. To complement the outcomes offered by D'Adamo and Rosa, some studies on the performance of four countries are individually reviewed: Germany (Lutz, Fischer, Newig, & Lang, 2017), Finland (Mälkki, Alanne, & Hirsto, 2015), Croatia (Borozan, 2017) and Ireland (Denny, O'Mahoney, & Lannoye, 2016). The analysis of the performance of the renewables per Erdil and Erbiyik (2015) held in Turkey determined that the compliance of the energy targets had higher priority than the environmental. This study took under consideration all the RE sources, especially hydraulic, and the outcomes certified that REs contribute in a high percentage to the Turkey's electricity generation.

One specific case from Africa is considered, the research carried out by Twaha et al. (2016) suggests alternative generation in Uganda to fight the current challenges faced by the energy sector and to provide the disfavored part of the population with electricity. Uganda has a good potential to develop renewables, however, it is one of the countries with the lowest electricity penetration level, less than 12% of the total population.

One specific case from Asia is considered, the idea of implementing a solar approach at a home level in Bangladesh. The Authors analyzed the energy problems in the country and advised policy developers with a strategy that could maximize the benefits of solar energy to contribute enhance the comfort of the society and the economy of the country to some extent (Hossain, Hossain, & Uddin, 2017).

The last research considered took place in the most advanced Latin America country regarding energy production by Aquila et al. (2016). According to the researchers, Brazil faces barriers that stop it to perform its full potential. For instance, wind and solar powers are reserved just in the case of hydrological risks, however, they might directly contribute to the generation networks.

As an oil producer country, Ecuador has always depended on fossil resources to fulfill the demand of energy as the rest of Latin America (Brutschin & Fleig, 2016). However, at the very first year of this millennium, the 71.70% of the 3,118.00 MW produced came from hydraulic plants, which was the only RE in the country by that time (Agencia de Regulación y Control de Electricidad, 2001). The rest came from non-renewable thermal sources: 14.25% generated by gas plants, 3.10% by internal combustion engine (ICE) plants and 10.95% by vapor plants. Taking into consideration the research of Shakouri and Aliakbarisani (2016), it is very conspicuous to say that the renewable energies were and will keep being the best option for the sustainable development of this small South American nation due to the natural resources, economic stability and energy regulation.

In 2006 the Ecuadorian government launch a project to expand the number of hydroelectric plants and the inclusion of other type of renewables as well (Agencia de Regulación y Control de Electricidad, 2007). This project intends to build several Eolic, photovoltaic solar, geothermal and biomass plants, as well as eight hydroelectric plants in the national territory.

Table 1. Hydroelectric projects in Ecuador since 2006

Project name	Location	Capacity [MW]
Coca Codo Sinclair	Between the provinces of Sucumbios and Napo	1500
Quijos	In the province of Napo	50
Manduriacu	Between the provinces of Pichincha and Imbabura	60
Toachi Pilatón	In the limit of the provinces of Pichincha, Santo Domingo de los Tsáchilas and Cotopaxi	253
Sopladora	Between the provinces of Azuay and Morona Santiago	487
Mazar Dudas	In the province of Cañar	20.82
Minas San Francisco	Between the provinces of Azuay and El Oro	270
Delsitanisagua	In the province of Zamora Chinchipe	115

Table 2. Historic data of energy production in Ecuador

Energy Source	Power Central	Nominal Power	Year																
			2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
RENEWABLE	Hydraulic	MW	1558.80	1722.06	1733.40	1735.49	1732.50	1794.94	1785.73	2030.45	2032.52	2032.16	2215.19	2207.17	2236.62	2236.62	2240.77	2401.52	4418.18
		%	53.23	56.39	53.07	52.21	51.58	51.13	47.49	49.03	48.62	46.23	46.56	46.02	44.18	43.83	42.29	43.22	58.09
	Biomass	MW	-	-	-	-	28.00	55.60	63.30	63.30	94.50	94.50	93.40	93.40	93.40	93.40	136.40	136.40	136.40
		%	-	-	-	-	0.83	1.58	1.68	1.53	2.26	2.15	1.96	1.95	1.84	1.83	2.57	2.45	1.79
	Eolic	MW	-	-	-	-	-	-	-	2.40	2.40	2.40	2.40	2.40	2.40	18.90	21.15	21.15	21.15
		%	-	-	-	-	-	-	-	0.06	0.06	0.05	0.05	0.05	0.05	0.37	0.40	0.38	0.28
	Solar	MW	-	-	-	-	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.04	0.08	3.87	26.37	25.50	25.59
		%	-	-	-	-	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.08	0.50	0.46	0.34
	Biogas	MW	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.76
		%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.02
Total Renewable		MW	1558.80	1722.06	1733.40	1735.49	1760.52	1850.56	1849.05	2096.17	2129.44	2129.08	2311.01	2303.01	2332.50	2352.79	2424.69	2584.57	4603.08
		%	53.23	56.39	53.07	52.21	52.41	52.72	49.18	50.61	50.94	48.44	48.58	48.02	46.07	46.11	45.76	46.51	60.52
Total Non Renewa		MW	1369.78	1331.76	1532.59	1588.84	1598.54	1659.74	1910.83	2045.33	2050.77	2266.65	2446.38	2492.67	2730.44	2749.96	2874.39	2972.41	3003.03
		%	46.77	43.61	46.93	47.79	47.59	47.28	50.82	49.39	49.06	51.56	51.42	51.98	53.93	53.89	54.24	53.49	39.48
TOTAL		MW	2928.58	3053.82	3265.99	3324.33	3359.06	3510.30	3759.88	4141.50	4180.21	4395.73	4757.39	4795.68	5062.94	5102.75	5299.08	5556.98	7606.11

Table 3. Total energy production and percentage of renewables in each Ecuadorian province

Region	Province	Amount of centrals	Effective power	
			Total [MW]	Renewables [%]
Coast	El Oro	8	258,49	2,32
	Esmeraldas	4	231,32	0,00
	Guayas	19	1372,13	23,74
	Los Rios	3	149,2	37,67
	Manabi	6	197,77	0,75
	Santa Elena	2	122,15	0,00
Highlands	Azuay	6	1327,69	98,7
	Bolivar	0	0,00	0,00
	Canar	2	53,7	100,00
	Carchi	0	0,00	0,00
	Chimborazo	4	15,65	100,00
	Cotopaxi	8	28,86	100,00
	Imbabura	11	106,69	74,41
	Loja	8	38,79	55,75
	Pichincha	25	288,3	46,89
	Santo Domingo de los Tsachilas	0	0,00	0,00
	Tungurahua	6	444,26	99,26
Amazon	Morona Santiago	5	92,55	95,42
	Napo	7	47,77	17,39
	Orellana	72	382,79	0,00
	Pastaza	3	48,59	0,00
	Sucumbios	74	324,94	0,00
	Zamora Chinchipe	1	2,4	100,00
Islands	Galapagos	12	19,02	32,73
Total		289	5556,99	46,51

Figure 1. Percentage of coverage of electricity utility users in Ecuador per year

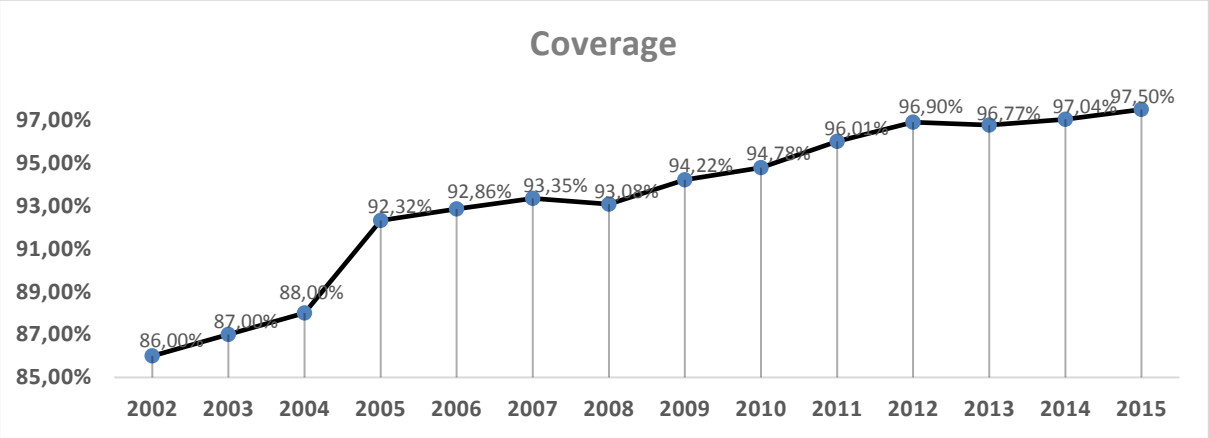
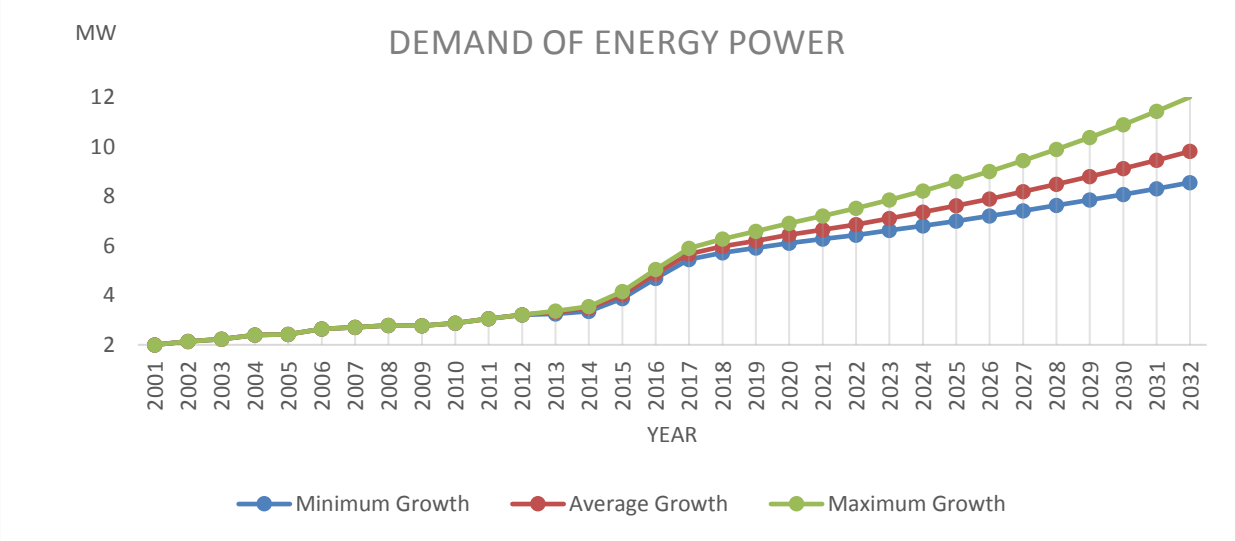


Figure 2. Evolution of the energy demand and estimation until 2032



The table 1 lists the hydroelectric projects and their capacities as presented in MPE 2013-2022 (Ministerio de Electricidad y Energía Renovable, 2013a).

Since 2007 the current administration has released the Master Plan of Electrification (MPE) (Ministerio de Electricidad y Energía Renovable, 2007, 2013b) that considers the exploitation of clean energy, in lieu of the conventional thermals, as one of the vital points in the reshape of the energy matrix for greater local and regional development. The MPE is part of the most ambitious national project, which consist in a positive change in the production matrix (Secretaría Nacional de Planificación y Desarrollo, 2009, 2013). This plan intends to serve the whole population but it results particularly advantageous to give service to rural areas without access to the current electric network.

By the year 2015, Ecuador counts with three Eolic, five photovoltaic solar, four biomass and nineteen hydraulic plants. The country produced 5,556.99 MW divided in 53.49% from non-renewable sources (27.82% ICE, 17.60 gas and 8.07% vapor) and 46.51% from non-renewable (0.38% Eolic, 0.46% photovoltaic solar, 2.45% biomass and 43.22% hydraulic).

The table 2 presents a compilation of data, between 2000 and 2016 (Agencia de Regulación y Control de Electricidad, 2001, 2002, 2012, 2016), about the national energy production that not only demonstrates the growth of energy demand in Ecuador but also shows the progressive addition of renewable energies in the National Interconnected System.

3. Ecuador Strategy for Energy Sustainability

Ecuador is currently exploiting alternative supplies coming from inexhaustible resources that incur in much less negative impacts, compared to oil sources, related to social, economic and environmental contexts. The table 3 presents a summary of the total amount centrals in each province of Ecuador, as well as the total energy produced and the percentage of renewable energy contribution.

Per the Ecuadorian Ministry of Electricity and Renewable Energy (MEER), the coverage of the electricity utility reached the 86.00% of the population

in 2002. Whereas it covered the 97,04 % in 2014 (Ministerio de Electricidad y Energía Renovable, 2014). The figure 1 shows this growth of coverage.

National and local entities have committed to promote and implement a series of actions to take better advantage of the energy resources. The MEER estimates an increment of 6.864 MW in the electricity demand in 2022 (Ministerio de Electricidad y Energía Renovable, 2013b). The figure 2 displays the estimation of future demand.

The MEER envisions the aggregation of electric public transportation in various cities, the swap of gas stoves by electric ones, the incremented production of diverse industrial sectors, the implementation of energy efficiency models for public buildings and street lighting, and the use of energy-saving appliances by the year 2022 (Ministerio de Electricidad y Energía Renovable, 2013a). This changes will convey to a positive increase of the demand of electricity, which will mostly come from reliable renewable sources that provide low-cost clean energy as stated in the Master Plan of Electrification 2013-2022 (Ministerio de Electricidad y Energía Renovable, 2013c). This plan promotes the effective development of the energy efficiency under the guidelines of the Good Living National Plan set by the Ecuadorian Government in 2013 (Secretaría Nacional de Planificación y Desarrollo, 2013).

Once all the new generation plants are put into operation the regime expect to stop the importation of electricity from its neighboring countries, Colombia and Peru, but also a substantial increment of the exportation instead. A great future for the generation of electricity in a sustainable way is foreseen in Ecuador.

The energy sector has a significant function in the socioeconomic development of each nation. In this sense, the efforts of the Ecuadorian Government to achieve a sustainable energy sector has a higher importance. However, the concept of sustainability may be understood and implemented taking under account the contexts and interests behind each project (Cinelli, Coles, & Kirwan, 2014). Selecting the best option to assess the sustainability of the energy systems are based in several criterion. The most common social, economic, technical and environmental indicators are: cost of investment, global warming, generation of employment and energy efficiency. In the context of mixed dimensions, safety of supply (techno-economic) and visual impact (socio-environmental) are the indicators with the highest frequency of usage (Martín-Gamboa, Iribarren, García-Gusano, & Dufour, 2017).

According to the inventory of the energy resources related to electricity generation carried out by the Ecuadorian Administration in 2015, there exists a total of 114 projects, divided into small, medium and big based in their capacity. The maximum achievable capacity would be 12,319.87 MW (Agencia de Regulación y Control de Electricidad, 2015).

4. Impacts of renewable energies

To complement the information learned so far, it is worth reviewing other impacts that the utilization of renewable energies cause to the country. It follows a short examination of some of these impacts:

4.1. Economic Impact

The performance of the energy sector is a determining factor of the progress of any nation. It is compulsory that providers estimate future demands to supply the required amount of energy continuously and efficiently. According to Edomah (2016), the increment of the participation of renewable sources will not only allow achieve this requirement but it will also allow the reduction of thermoelectric generation to attain a sustainable production in the country.

Per Sen and Ganguly (2015), the economic growth and a higher people's purchasing power will definitely influence in a positive way the increment of the energy demand and consumption. Throughout this new millennium the Ecuadorians have experienced a significant increment (391.56%) of the gross national income (GNI) per capita as the World Bank (2016) has indicated. Because of this raise of the GNI, the energy consumption per capita has also incremented in a 45.14% in 2015 compared to the end of the year 1999. The 46.51% of the 1162.64 kWh/user consumed in 2015 came from RE sources (Agencia de Regulación y Control de Electricidad, 2016). All these changes incur positively in the economy. In a macro vision, the higher purchasing power the inhabitants have, the more energy they consume, dynamizing the cash flow within the country. The industrial sector, including factories and business, represented the 41.15% of the total demand of electricity, which definitely uphold the Ecuadorian economy.

In a micro vision, the MPE considers the reliable supply of clean energy at a reasonable price (Ministerio de Electricidad y Energía Renovable, 2013c). It also contemplates the construction and operation of new generation centrals as well as new factories and companies that will offer new job vacancies to support the current employment demand. For instance, the project Mandariacu alone triggered more than 2400 job contracts. All this enhances the productivity and delivers a long-term economic stability.

4.2. Social impact

The social behavior of the residents of a country are a fundamental aspect for the acceptance of RE generation and its long-term support. As Sheikh, Kocaoglu, and Lutzenhiser explained (2016): assessing the people's reaction, as well as the advantages and disadvantages for the society, when implementing renewables in a country let establish a sustainable energy strategy aligned with the social standards entrenched. The access to high-quality energy is one of the requisites for the human develop-

ment and contributes to increase the number of job opportunities, the enrichment of health services, the upgrading of education and to decrease the poverty level (Kaygusuz, 2007).
The main point identified from a social perspective is development of the local infrastructure which will convey in an enhancement of the communities. For instance, and continuing with the project Mandariacu, it encouraged the construction of new houses and businesses, the provision of utilities and the development of compensation works for the community as well (Odebrecht, 2015). In addition, 800 of the job openings were filled by residents of the local communities. As an effect of developing this project, the workers were trained in safety standards, equipment operation and electric risks to perform an efficient job. Also, the project guaranteed health, road safety, environmental protection and promotion of local culture in each of the communities involved. Nowadays, many of the residents are a part of the work team controlling the hydroelectric operation or are working in other national projects.

4.3. Environmental Impact

Although it is confirmed that RE will reduce the carbon footprint, they will cause collateral effects in the environment. A study on the development of renewable energy in Iran's rural areas demonstrated that several environmental issues might arise (Afsharzade et al., 2016). The study carried out by Sokka et al. (2016) in Finland is a partial assessment of the impacts of the energy generated by renewable sources concerning the life cycle, including toxicity, biodiversity repercussion, soil depletion, water and land use, radiation, plant, pests and diseases.
Environmental global metrics have been instituted in order to take decisions on climate change based on the international regulatory framework. The Environmental Performance Index (EPI) proposed by Yale University suggests two high-priority areas: human health protection and ecosystems conservation. Nonetheless, EPI evaluates nine areas using twenty indicators (Hsu, 2016). According to this index, Ecuador ranks 103rd in the year 2016. The MPE shows the estimation of environmental effects but the outcomes does not show any major issues to the Ecuadorian ecosystem (Ministerio de Electricidad y Energía Renovable, 2013a).

5. Conclusions

Around the globe the integration of renewables in the energy system is a reality that not only includes the infrastructure but also an important and favorable change in the energy policies. Each nation has to be analyzed as unique, and hence, the new policies should be written regarding the political, economic and environmental status of each country, as well as the culture and social behavior of its inhabitants. However, specific contemplations from other nations might be emulated if correlations exist.
Ecuador has adopted long-term policies (the Master Plan of Electrification 2013-2022) as a mean to change the energy matrix. It has contributed to raise the awareness of the efficient utilization of the natural resources and encourage the clean generation of renewable energy for the years to come.
Despite all the possible significant benefits this sustainable development might carry out, a variety of economic, political and legal obstacles stop them to reach their full potential. The restructure of the policy of renewable energy would support the development of Ecuador considering the future needs of energy but also guaranteeing a proper environmental preservation.
The inclusion of FIT in several countries' policies tend to be a success, however, it is imperative to analyze its future application in Ecuador because they are not always the best approach to encourage the implementation of renewable energies. The manufacturing of renewable technology in the country might cut prices on projects, unluckily, Ecuador does not make this type of technology. Instead, the release of governmental initiatives for the importation of equipment, including the reduction of customs duty and internal taxes, might stimulate the development of renewable generation. Ecuador and most of the Latin American countries present regulatory uncertainties, being the reason other type of legal initiatives should be set and some incentives should be granted for the generation and efficient use of potential renewable energies other than hydroelectric.
The replication of a mathematical sustainable model in order to evaluate the long-term electricity supply-demand in Ecuador and Latin America might be performed by taking under consideration the modelling proposed by Ouedraogo (2017) for the African Continent.
A positive acceptance of the renewables is expected not only in the country but also in the region to achieve the so pursued South American integration.

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