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## ASSESSING THE CURRENT STATUS OF THE ELECTRICITY SECTOR OF THE GALAPAGOS ISLANDS

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*Assessment of the current status of the electricity sector of the Galapagos Islands in Ecuador, including all the populated islands, is undertaken in this study. The analysis is mainly carried out using the current data for 2020 and the forecasts estimated for 2025 by the Ministry of Electric Power of Ecuador. This archipelago, with five populated islands, has a high dependence on fossil fuels for the generation of electrical energy (80% of the total installed power is running on diesel). On the other hand, even with a high existence of sea waves, solar, and wind resources on the islands, less than 20% of its energy matrix uses these renewable resources. However, in the upcoming 5 years, it is intended to install almost 30 MW of this renewable energy not only to use the existing resources but also to reduce greenhouse gas emissions. Furthermore, new sustainable development policies, such as zero-fossil fuel in the Galapagos are launched in order to decrease the use of thermoelectric power plants. Finally, even with the existence of several plans to install renewable energy plants and the new sustainability policies, the future of this archipelago is also highly dependent on energy efficiency programs as well as external investment.*

**Keywords:** Galapagos Islands, Power generation on islands, renewable energies, energy policies.

### 1. INTRODUCTION

The Galapagos archipelago, one of the twenty-four provinces of Ecuador is located about 972 km off the coast of mainland Ecuador in the Pacific Ocean, and it is considered as the unique “living museum and showcase of evolution” worldwide due to their high number of endemic species (UNESCO, 2018). This exclusive biogeographical region has a total area of 8233 km<sup>2</sup>, where consisting of thirteen large islands with an area greater than 10 km<sup>2</sup>, six islands of medium size with an area that varies between 1 km<sup>2</sup> to 10 km<sup>2</sup>, and 215 small islands (CGREG, 2016).

The administrative political division of the Galapagos province includes three cantons: Santa Cruz, San Cristobal, and Isabela. The capital of the province is Puerto Baquerizo Moreno, located on the Island of San Cristobal. 83% of the population is located in the urban area and 17% in the rural area of the islands. Approximately 26,000 people live in this archipelago, with an annual population growth rate of almost 2%. Besides, the population is mostly distributed among five islands: 30% in the San Cristóbal canton in the Floreana and San Cristóbal Islands, 61% in the Santa Cruz canton in the Santa Cruz and Baltra Islands, and 9% in the Isabela canton in the island with the same name. Table 1 presents the general characteristics of the populated islands (INEC, 2015).

Regarding temperature, the Galapagos climate includes a hot season that ranges between 26 °C and 28 °C occurring between January and April. The cold season occupies the rest of the year with temperatures below 24 °C; certain western locations register temperatures of only 14 °C. During the months of the rainy season (June to November) the average ambient temperature on the coasts of the islands is 21 °C (GADMI, 2012).

Lastly, due to their vast biodiversity and high levels of endemism, the Galápagos Islands are recognized internationally for their multiple protected areas and designations, such as Galápagos National Park, Biosphere, and Whale Sanctuary, Marine Reserve of the Galápagos, and Natural Patrimony of the Humanity. As a result of its biodiversity, Galápagos has become an icon of tourism, generating a series of economic, environmental, social, and cultural effects (DPNG, 2014) and (Lansdale et al., 2015).

Table 1. General Characteristics of the Populated Islands (CGREG, 2016).

Island	Characteristics
Floreana	Located in the south-central area of the archipelago, it has an area of 172 km <sup>2</sup> , with a maximum altitude of 640 meters above sea level. The age of the island is estimated at approximately 1.5 million years.
Isabela	Positioned in the west of the archipelago, it is the largest island in the province with an area of 4588 km <sup>2</sup> , representing 60% of the total area of Gal�pagos. This island is one of the youngest being less than a million years old. One of the most volcanically active islands because it is in a hot spot.
San Crist�bal	Situated to the east of the archipelago, further away from the hot spot, this island has an area of 558.09 km <sup>2</sup> , and its altitude is 730 meters above sea level. San Crist�bal is the oldest island with an approximate age of 2.8 to 5.8 million years.
Santa Cruz	Located in the center of the archipelago. It is one of the largest islands, with an area of 986 km <sup>2</sup> and a maximum altitude of 864 meters above sea level. It is estimated to be 3.6 million years old.
Baltra	Located in the center of the archipelago as well, close to Santa Cruz. The area is 72 km <sup>2</sup> and has a maximum altitude of 100 meters above sea level.

On the other hand, the Galapagos Electricity Sector (GES) is divided into three periods (ARCONEL, 2015). The first period, which occurs from 1961 to 1999, was marked by the emergence of the electrical energy on the Galapagos Islands. The second period, which occurs from 1999 to 2007, was marked by the increase of the coverage service on the islands. Both, period one and period two were also marked by diesel consumption to produce electricity. No renewable power plants to produce energy were reported in those periods (Llerena et al., 2019). This dependence on diesel caused environmental impacts on the archipelago (SGR, 2018).

For example, in January 2001, the ship Jessica, owned by Acotramar, ran aground at the entrance of Puerto Baquerizo Moreno on San Crist bal Island. The vessel was carrying ca. 600 tons (160,000 gallons) of diesel and ca. 300 tons (80000 gallons) of gasoline. As a result, seven sea lions and 17 birds (pelicans and blue-footed boobies) on San Crist bal Island were harmed by the spilled fuel. On Santa Fe Island, several sea lions were also affected, while 62% of the iguanas were dead within one year of the spill occurring (Sanderson and Villanueva, 2001) and (El Universo, 2002).

A similar accident occurred in June 2011, when 700 gallons of diesel were spilled in a bay on Santa Cruz Island, the Gal pagos Island most visited by tourists. Fortunately, in this case, the spill was controlled due to the placement of a protective barrier around the wreck, preventing damage to the flora and fauna (El Universo, 2011).

In the last period, which occurs from 2007 to 2020, a participation of renewable energy was reported. In this period, almost 15% of renewable resources to generate electricity were added to the electric matrix of Galapagos (Llerena et al., 2019).

The details of the GES and the forecast for the upcoming 5 years will be presented in the following sections of this paper.

## 2. GALAPAGOS ELECTRICITY SECTOR

Human settlements in Galapagos are recent. The few people who lived on the islands 80 years ago had a series of needs, one of which was electricity. To partially cover this need, these inhabitants used the hours of the sun to the maximum and in the evenings, they used candles. However, populations grew and so did the needs. That was how a group of islanders organized themselves to look for ways to generate electricity. When this resource was obtained, the few streets of the islands were lit for a few hours during the night, until in 1971 the Institute of Electrification of Ecuador (INECEL, acronym in Spanish) began electrification in the archipelago (ELECGALAPAGOS, 2017).

### 2.1 Total installed power

The Galapagos electricity Matrix is an isolated electrical system of the Ecuadorian interconnected system, which feeds energy to each populated island. The total power installed is about 35 MW, where 85% comes from non-renewable resources and 15% comes from renewable resources (vegetable oil, wind, solar). Santa Cruz is the bigger station with more than 50% of the total power installed in the archipelago (19 MW), followed by San Cristobal with almost 12 MW, Isabela with 4 MW, and Floreana with less than 1 MW (Llerena et al., 2019). Table 2 summarizes the total power installed in the Galapagos Islands.

Table 2. Total Installed Power in the Galapagos Islands (MEER, 2017; MEER, 2017; and ELECGALAPAGOS, 2017).

Island	Thermoelectric Power Plants			Renewable Energy		Total
	Installed Power	# of Diesel Generators	Performance (kWh/gallon)	Installed Power	Type of Energy	
San Cristobal	9.40 MW	9	13.04	2.4 MW 0.12 MW	Wind Energy Solar	35 MW
Baltra & Santa Cruz	15.0 MW	11	13.77	2.2 MW 1.5 MW	Wind Energy Solar	
Isabela	3.2 MW	5	13.21	0.93 MW	Solar	
Floreana	0.16 MW	2	11.47	0.18 MW 0.026 MW	Vegetable oil Solar	

As shown in Table 2, the GES is highly dependent on fossil fuels with a total installed power of 27.7 MW. On the other hand, renewable resources just start to appear in this electricity sector with a total installed power of 7.3 MW mainly distributed on solar and wind energy plants. A plan for 2025 is to increment in 100% the capacity of this matrix only with renewable resources. In other words, almost 35 MW will be installed in the upcoming years (MEER, 2017; Llerena et al., 2019; and CONELEC 2013). Fig. 1 shows the forecast for 2025.

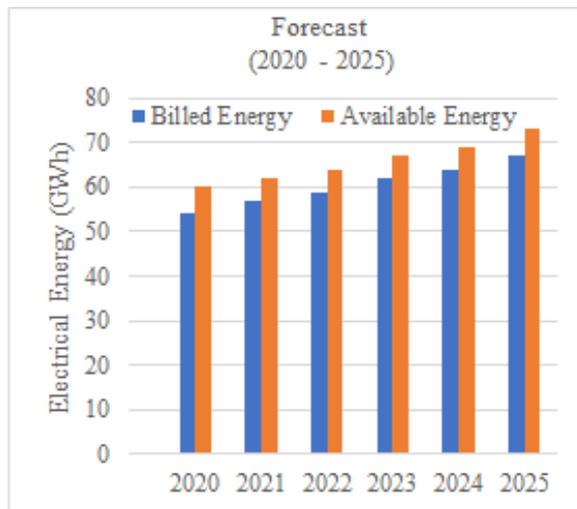


Figure 1. Forecast of energy consumption and generation in the GES for 2025 (CONELEC, 2013; Llerena et al., 2019).

In Figure 2, it is possible to observe the electricity generation matrix in the province of Galapagos, currently influenced by unconventional generation plants.

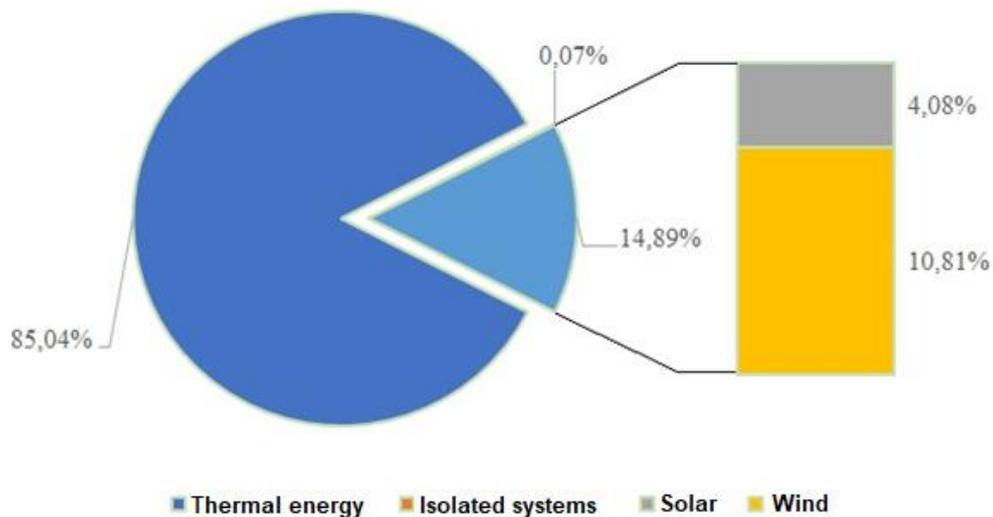


Figure 2. Galápagos electric power generation matrix 2018.

## 2.2 GES growth in recent years

As far as the nominal installed power is concerned. Table 3 summarizes the nominal powers of the power plants according to the type of energy, for the years 2007 and 2016.

Table 3. Nominal powers of the power plants (2007 – 2016).

Type of energy	Number of generators		Nominal Power (MW)		Variation (MW)
	2007	2016	2007	2016	
Thermoelectric	4	4	9,86	22,21	12,35
Wind	0	2	0	4,65	4,65
Photovoltaic	1	7	0,02	1,64	1,62

Similarly, between 2007 and 2016, there was an increase of 4.205 customers, representing 59.82%. Table 4 shows the customer groups for 2007 and 2016.

Table 4. Customers between 2007 and 2016.

Year	Group of customers					
	Residential	Commercial	Industrial	Public	Others	Total
2007	5.617	1.006	143	4	259	7.029
2016	8.825	1.834	178	28	369	11.234

## 2.3 Rates in the GES

The ARCONEL, in accordance with Article 15, Powers and Duties of the Organic Law of the Public Electric Power Service (LOSPEE, for its acronym in Spanish), has the power to carry out technical, economic, and financial studies and analyses for the preparation of regulations, rates specifications and control actions for the public electric power service and the general public lighting service (Asamblea Nacional, 2015).

The GES operates with two main rates. The normal rate, which is about US\$ 0.11 per kWh, and the tariff of dignity, which is about US\$ 0.04 per kWh. The second one is for all users that consume less than 130 kWh/month. The GES also applies a different rate for other sectors, for example, for the industrial sector is applied the highest tariff (US\$ 0.13). The highest history peak in the rates in the GES was in 2018 (US\$ 0.23) for the lighting sector (ELECGALAPAGOS, 2018; ARCONEL, 2017; ARCONEL, 2018).

## 2.4 The GES Infrastructure

The current GES infrastructure has 9 substations (41.3 MVA). The total transmission lines are about 52 km. Besides, at the distribution levels, this system consists of 270 km of medium voltage lines (147 km of 13.2 kV and 123 km of 13.8 kV), 210 km of low voltage lines (190 km single-phase, 1 km two-phase, and 17 km three-phase), 854 transformers (718 single-phase and 136 three-phase) with transformation capacity of 28.97 MVA (18.46 MVA single-phase and 10.52 MVA three-phase) and almost 11,500 measuring devices (ARCONEL, 2019; MEER, 2017; ELECGALAPAGOS, 2013). The total electricity coverage is 93% and it is expected to be 99% in 2025.

## 3. GENERATION EXPANSION IN THE GALAPAGOS PROVINCE

According to PME 2016 - 2025 (MEER, 2017c), US\$ 114 million will be needed to carry out 14 projects to improve and expand the Galapagos province's electric generating matrix by 2025. Four of these projects are a priority and have 100% financing.

The Isabela Hybrid System project. This project has a cost of almost 12 million dollars and has 100% of the budget thanks to the non-refundable financing of the Financial Cooperation of the Government of Germany, through the Development Bank (KfW) (MEER, 2017a). The main objective is this project is to introduce renewable energy sources for electricity generation through the use of solar irradiation and the use of biofuels (ELECGALAPAGOS, 2018a).

The San Cristobal Hybrid System Automation project. This project aims to achieve the maximum penetration of renewable energy in the electricity grid of San Cristobal. An energy contribution of 3.9 GWh/year from the installed wind farm is expected, in addition to a reduction of 350 thousand gallons/year of diesel, which will avoid the emission of approximately 3148 tCO<sub>2</sub>/year. The referenced budget is 500 thousand dollars (MEER, 2017c).

The Second Phase project of the Baltra wind farm - Santa Cruz. This project aims to expand the wind farm on the island of Baltra, through an increase of 4.75 MW of power. Thus, it is estimated to achieve an energy contribution of approximately 12 GWh/year, and a reduction of approximately 1 million gallons/year of diesel, avoiding the emission of 7200 tCO<sub>2</sub>/year. The referential budget is \$ 16 million. (MEER, 2017c).

The Baltra Island Photovoltaic Extension project. This project aims to expand the photovoltaic park in Baltra, through an increase of 200 kWp of power. Thus, the new system will contribute 140 MWh/year, reducing approximately 12000 gallons/year of diesel, avoiding the emission of approximately 84 tCO<sub>2</sub>/year. The budget was estimated at US\$ 1 million (MEER, 2017c).

In addition to these short-term projects, intending to ensure the economic development of the archipelago due to the preservation of the environment, Galapagos has a long-term expansion plan for the electric generator park. Currently, these projects do not have funding and are in the conceptual phase. Table 3 shows the main long-term projects.

Table 3. Long-term expansion projects.

Island	Project	Power	Year	Cost (Million USD)
San Cristobal	Photovoltaic	1,4 [MWp]	2021	8,5
	Photovoltaic	3,1 [MWp]	2023	18,5
	Wind	2,25 [MW]	2021	9,5
	Wind II	2,25 [MW]	2023	9,5
	Photovoltaic	2,1 [MW]	2021	12
Baltra Santa Cruz	Wind	4,75 [MW]	2023	20
	Photovoltaic II	3,1 [MW]	2023	18
Isabela	Photovoltaic	1,5 [MWp]	2021	9
	Photovoltaic II	1,5 [MWp]	2023	9
Floreana	Photovoltaic	0,2 [MWp]	2023	1,5

#### 4. CONCLUSIONS

An assessment of the current status of the electricity sector of the Galapagos Islands in Ecuador, including all the populated islands, was undertaken in this study.

The analysis was carried out using the current data for 2020 and the forecasts estimated for 2025 by the Ministry of Electric Power of Ecuador. From the results, it was observed that this archipelago has a high dependence on fossil fuels for the generation of electrical energy (80% of the total installed power is running on diesel).

Even with a high existence of sea waves, solar, and wind resources on the islands, less than 20% of its energy matrix uses these renewable resources. However, it was found that in the upcoming 5 years, it is intended to install almost 30 MW of this renewable energy.

Furthermore, new sustainable development policies, such as zero-fossil fuel in the Galapagos are launched to decrease the use of thermoelectric power plants.

Finally, even with the existence of several plans to install renewable energy plants and the new sustainability policies, the future of this archipelago is also dependent on energy efficiency programs as well as international investment.

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