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Spatial assessment of the potential of renewable energy: The case of Ecuador

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ABSTRACT

Although renewable energy represents a large share of the electric energy generation sources in Latin America, non-conventional sources such as solar or wind energies have not represented a big share of their electric energy systems. The first step to promote the use of these sources in the region is identifying the potential of each energy source, task that can be estimated with the use of spatial tools such as Geographic Information Systems (GIS). This study has reviewed a large list of GIS publications to select a methodology to identify suitable areas for the development of non-conventional renewable energy projects (REP), in order to estimate the maximum energy these technologies could contribute to a national electric energy system, and its applied to the Republic of Ecuador. By using GIS, it is sought to identify the sites where potential renewable energy plants could be located, and initially recommends geographic locations for the installation of measuring towers of solar and wind resources, in order to obtain more detailed information on their behavior. As a result, the areas with higher potential for the development of REP have been identified, and classified in spatial layers according its technology and location. These results show that solar PV is the technology with most suitable areas in the country and demonstrate particularly large potential in two regions: the Andes cordillera and Insular region, especially in the provinces of Loja, Pichincha and the Galapagos islands.

1. Introduction

Whilst Non-Conventional Renewable Energy (NCRE) sources are increasing its share in most energy systems worldwide, the participation of these technologies in the majority of developing countries has not shown greater increase of installed capacity, and energy generated, during the last decade [1]. Besides Hydropower and biofuels, renewable energy has not played a significant role in the energy sector in the Latin-American region, although this trend has started to change thanks to the construction of some renewable energy projects, and public policies encouraging the development of clean energy generation projects [2]. If the goal of reducing greenhouse gas emissions is to be achieved, it is necessary to keep track to the growing economies of developing regions, which are projected to increase in energy demand and production.

Nowadays some countries in Latin America have achieved (or are close to) a complete renewable energy electricity grid, using a mix between hydropower and other NCRE. Examples of this are Costa Rica, Paraguay and Uruguay, which now satisfies more than 90% of their electric power demands using hydro, wind, or a mix of both [3]. Since 2016, Ecuador is trying to join these countries with an almost sustainable electric grid thanks to the construction of eight hydro power plants summing an installed capacity of 2.76 GWp and some minor capacity of NCRE [4]. As it can be seen in Fig. 1, Ecuador is a country filled with natural resources, and for decades has been able to use them to produce electricity. Despite the government has encouraged the expansion of renewable energy technologies in the country, through the issuance of various regulations that promote their participation [5–8], the share of NCRE power plants in the national energy balance was still below one percent in 2016. However, the few NCRE power plants that have been commissioned in the country have proven to be highly effective. One example of this is the Villonaco wind farm, which in 2014 showed a capacity factor of 53%, which is considerably high compared to the average capacity factor for this type of plants. Solar Photovoltaic plants have also shown high efficiencies, thanks to the privileged position of the country regarding the sun. Because of the high effectiveness of the projects mentioned, it is of great importance to promote the use of these technologies in the region.

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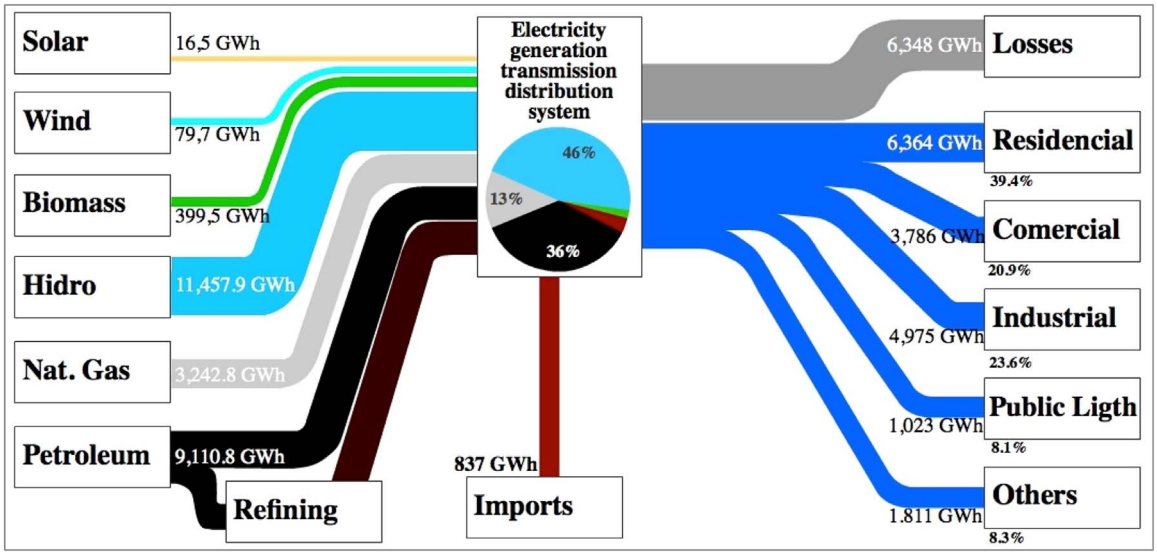

Fig. 1. Ecuadorean electric power system in 2014 [27].

Similar studies related to the location of suitable areas for different purposes can be found in almost every region of the planet. Studies carried out by Bravo et al. [9], and Ramachandra and Shruthi [10], have used Geographic Information Systems (GIS) approach to evaluate potential areas of multiple renewable energy technologies in Spain and Karnataka, India. Many other studies have focused in only one technology for the assessment of potential areas for RES projects. Although the methodology of each one varies according to the resource to be analyzed, most of them use GIS tools to carry out the processes required to determine the suitable areas of each technology. Assessments of the potential of Solar PV [11–13], and CSP [14–17], have been mainly performed in the regions with high solar radiation, most of them in North America, Africa, Australia, the Mediterranean and Middle East. Likewise, GIS assessments for the location of suitable areas are very popular for wind farm sitting [18–21], as it allows visualizing in advance the land surface where the plant will be implemented. The research performed by Tegou et al. [22], for instance, uses GIS tools to determine the suitability of land, for the construction of wind farms in the Lesvos island of Greece. In this case, the study uses multi-criteria analysis (MCA), and analytic hierarchy process (AHP), to evaluate each criterion according to its importance and establish a ranking among alternative sites.

This study focuses on the assessment of potential locations for the implementation of non-conventional renewable energy projects, in order to estimate the maximum theoretical amount of energy they could contribute to the Ecuadorean's energy system. By using Geographic Information Systems (GIS) tools, this study seeks to identify suitable areas where NCRE power plants could potentially be sited and classifies the results by regions. The evaluation can be used as a starting point to select the best locations for the installation of resource measuring towers, in order to obtain detailed behavioral data from these sources.

2. Material and methods

2.1. Description of the methodology

The use of GIS has been widely accepted on the location of suitable areas for the implantation of RES power plants. Nath et al. [23] described in his study the nine steps to perform a GIS project and the main factors to be taken into account to carry them out correctly for the goal of locating suitable areas. It also included the description of various case studies, and some the methodologies applied in each case. These nine stages are briefly described below:

a) Identifying the requirements of the project,
b) Formulation of specifications,
c) Development of the analytical framework,
d) Tracing data sources,
e) Organization and manipulation of the data,
f) Analysis of the data and outputs,
g) Evaluation of results.

The present study has followed these nine steps to identify the areas proposed in Section 1. Every step requires the participation of subject matter experts, GIS analysts and stakeholders in order to achieve accuracy in its results. Once each group of analysts has expressed their needs, they can begin to discuss how GIS can be used to fulfill them, also identifying the limitations of the use of these tools. Another important factor of the proposed model is the gathering of the necessary data to be used in the study, which typically consists of Vector and Raster images describing environmental, social, and economic information. These data can be obtained from primary sources like satellite and aerial imagery, or secondary sources like developed maps and layers of the region of study.

2.2. Technologies considered in the study

The proposed methodology can be applied to find potential areas for the implementation of all types of renewable energy projects. To meet the requirements of the model, for each technology, is necessary to have all the data needed to meet technical, environmental and social criteria. Each criterion will determine the minimum requirements in order to make each technology feasible; the lack of any of these criteria in the analysis could reduce the credibility of the results. Due to the availability of nationwide information from the solar and wind resources, the selected technologies for the analysis are: Wind energy, solar photovoltaic, and concentrated solar power, which are described next.

2.2.1. Wind energy

Wind is the most developed of the non-conventional RES, and its use has been spread in almost every country of the planet. This analysis takes into consideration only on-shore wind farms, because the resource raster files, containing national wind speeds, do not include wind speeds in marine regions of the country. According to various