An overview of the hydropower sector in Bolivia

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Abstract

Bolivia due to its topography and availability of water resources has a high potential for generating enough energy for covering its national demand. However, the lack of information, studies, projects and investment has led into a partial national coverage of electricity. The Bolivian grid is formed of the National Interconnected System (SIN) and Isolated Systems. Together they provide a national coverage of 93%, while in the urban area is 99% in the rural area is 80%. The installed capacity is composed of non-renewable thermal energy (67%) and renewable energy (42%). Where renewable energy is produced by different sources: hydroelectric (24.9%), solar (2.6%), wind (27.10%) and thermal sources (4.6%).

In the last two decades, energy from hydropower plants has increased by 48%. In 2009 it was reported a capacity of 496 MW and a production of 2,295 GWh. In 2019 the National Committee of Energy Distribution reported a capacity of 735 MW generated by the hydroelectric system of Taquesi, Kanata, Corani, Yura, Miguilla, Zongo, Quehata, San Jacinto and Misicuni which belong to eight companies between national and private. The theoretical hydropower potential in Bolivia is estimated to be around 178000 GWh/year. However, to the date the hydropower plants in Bolivia generate about 2500 GWh, which means that less than 2% of the theoretical potential has been developed so far. Most of this theoretical potential can be generated in the northeast of Bolivia.

Small scale hydropower plants showed good results in Bolivia, especially in those areas located in the northern part of La Paz which are isolated rural areas. However, the lack of clear national policies, rules, low energy prices limited the fully development of hydropower projects in Bolivia. About applied research there are only two universities in Bolivia that have research units dealing with hydropower topics (Hydraulic lab at UMSS, and Institute of Hydraulics and Hydrology at UMSA). It is important to improve the settlement of international companies in Bolivia that can offer training, equipment and materials for develop hydropower projects.

1. Introduction

Bolivia is a developing country that still needs to develop strategic economic and industrial activities in order to strengthen their national economy. The main activity that contributes to the economy in Bolivia is the oil and gas exportation. However, in the recent years, the oil and gas industry suffered worldwide several problems (i.e. decrease of prices), which directly caused a shrinking of the economy in Bolivia. Additionally, the existing gas reservoirs in Bolivia are near to be depleted, and the outcomes of new reservoirs exploration were not encouraging. As a consequence, the national government wants to strength the industrialisation of natural resources in Bolivia, where one of the lines is the construction and development of several medium and large hydropower plants. These new hydropower plants will be a key aspect for making Bolivia, in the near future, an exporter of renewable electricity. The interest of developing the hydropower sector is due to the geographic and climate conditions of Bolivia.

Bolivia has three main physiographic areas: i) to the west the dominating feature is the Andes range and it is characterized by arid climate, ii) to the east, the Amazon basin extends about 70% of the Bolivia's territory, iii) and in between them the subAndean valleys are located, which is a transition zone between the Andes and the Amazon. Most of the surface water offer is located towards the northeast (refer to Fig. 1), however the majority of the main cities of Bolivia are located in the subAndean and Andean regions where rivers are less abundant. However, most of the subAndean region are located in step terrain, as a consequence this region might be of interest for developing small hydropower plants. On the other hand, the Amazon basin in Bolivia has several rivers with average flows greater than 5000 m^3. Hence the location of medium to large hydropower are of high interest in this region. The average altitude along the Andean region is between 3750 and 4000 m.a.s.l. Within the subAndean zone, the altitude average is 2500 m.a.s.l. In the Amazon region the altitude varies between 400 and 90 m.a.s.l. The overall of this study is to briefly summarize different aspects or activities related to the

hydropower sector in Bolivia collected within the HYPOSO (Hydropower solutions for developing and emerging countries) project.

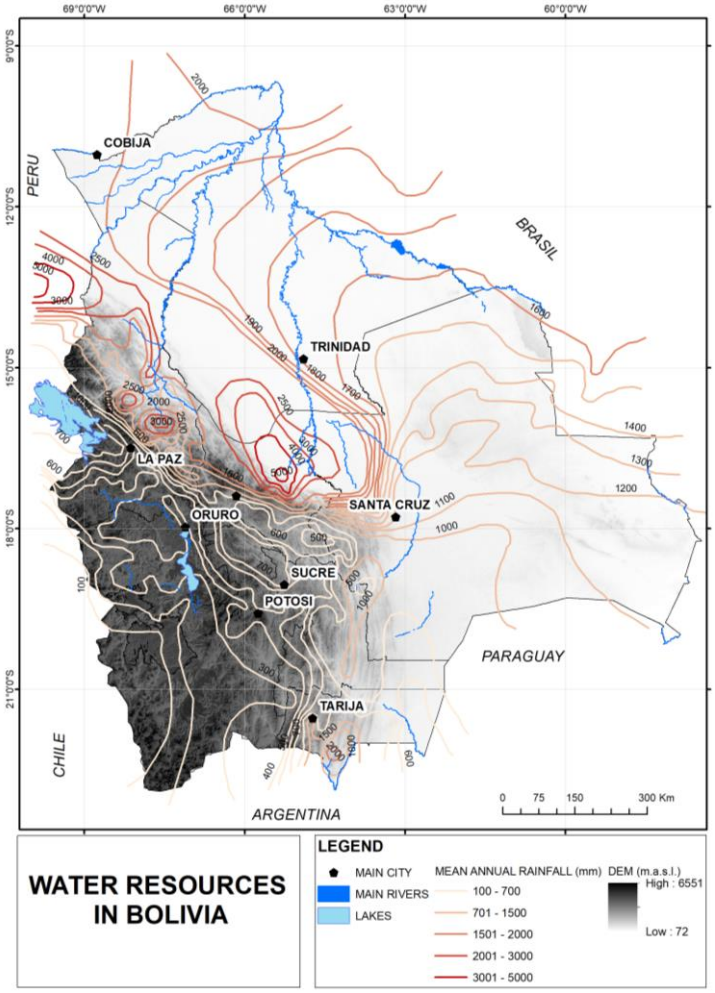

Fig. 1. Map showing the mean annual rainfall and main rivers Bolivia. It is possible to see that the terrain elevation in Bolivia vary significantly from 6551 to 72 m.a.s.l.

2. Hydrological overview

Although in Bolivia is very common to find basins with poor monitoring or gauging, the Ministry of Environment and Water of Bolivia, together with the Stockholm Environment Institute (Sweden) and Hydraulics Lab (Universidad Mayor de San Simon in Bolivia) elaborated a National Water Balance. The results from this study are very significant because it is now possible to access to data such as precipitation, evaporation (actual and potential), runoff, specific discharge, and different climate change scenarios. The availability of this information is an asset for performing evaluations about the location of potential hydropower sites in Bolivia.

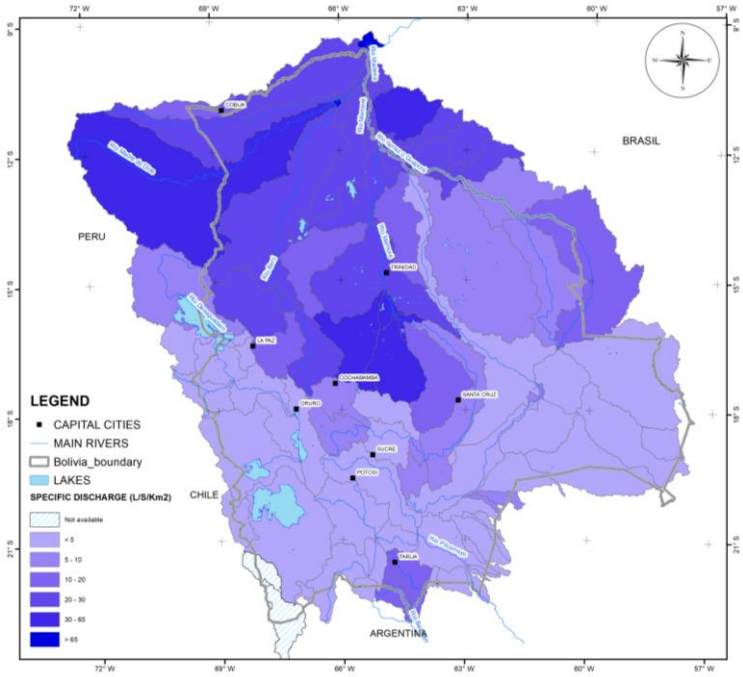

Fig. 2. Map showing the specific discharge of Bolivia. Modified from MMAyA (2018).

The national precipitation average is 640 mm, but there are some regions with precipitation rates greater than 5000 mm, and other regions with rates lower than 100 mm (see Fig. 3.a). In general, the precipitation pattern in Bolivia is not uniform either in time or in space, and as a consequence there are many urban centres with water deficit, specially those located in the western part of Bolivia. The runoff of Bolivia is more uniform. To the west and south the runoff rates are lower, while in the eastern parts of Bolivia the runoff rates are greater. Despite the precipitation and runoff rates are lower in the western regions of Bolivia, the changing and step topography offers good conditions for locating small and micro hydropower plants in these areas.

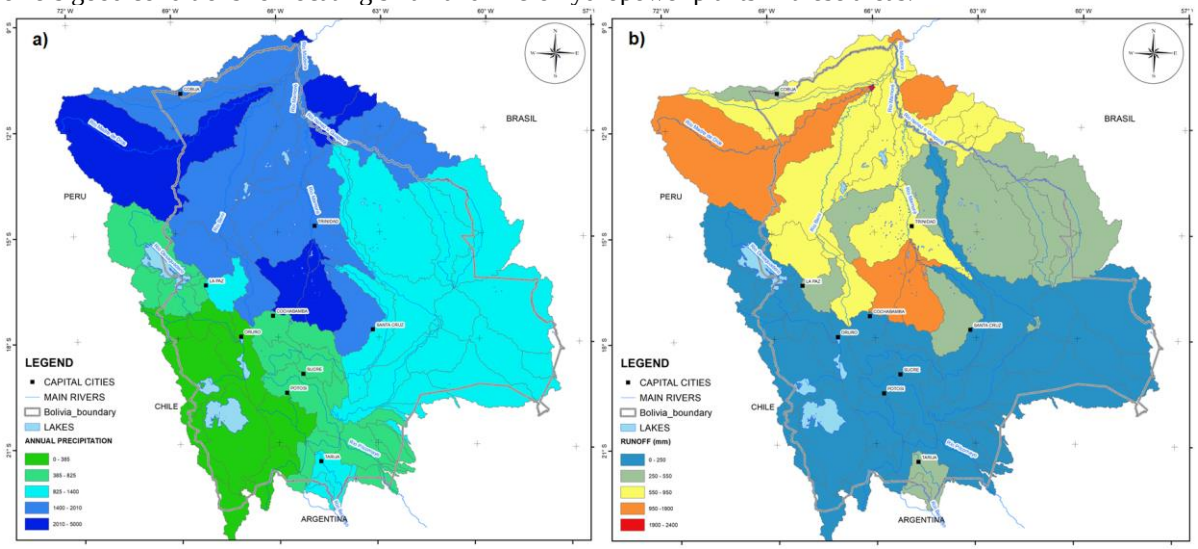

Fig. 3. a) and b) Map showing the mean runoff and annual precipitation and of Bolivia, respectively. Modified from MMAyA (2018).

3. Hydropower and industry overview

In Bolivia the national coverage of energy is in average 93%. While in the urban area is 99% in the rural area is 80%. Despite the high hydropower potential of Bolivia, the major share is covered by non-renewable resources such as natural gas combustion turbines. Now-renewable covers about 62% of the national production generating around 1538 MW. While the hydropower sector covers about the 30% of the national production, generating around 734 MW. Smalls shares are from geothermal and wind sources, which covers about 8% of the national production (Punys et al., 2020).

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The hydropower sector in Bolivia are mainly represented by medium and large plants. In 2019 about 26 hydropower plants were in operation (Fig. 4.a), with a total generation of 5289 MW. It is estimated that the investment cost for electricity generation is 2800 $us/KW, categorizing it as high investment compared to conventional technologies (natural gas and diesel), but with lower operating cost (ESMAP, 2012).

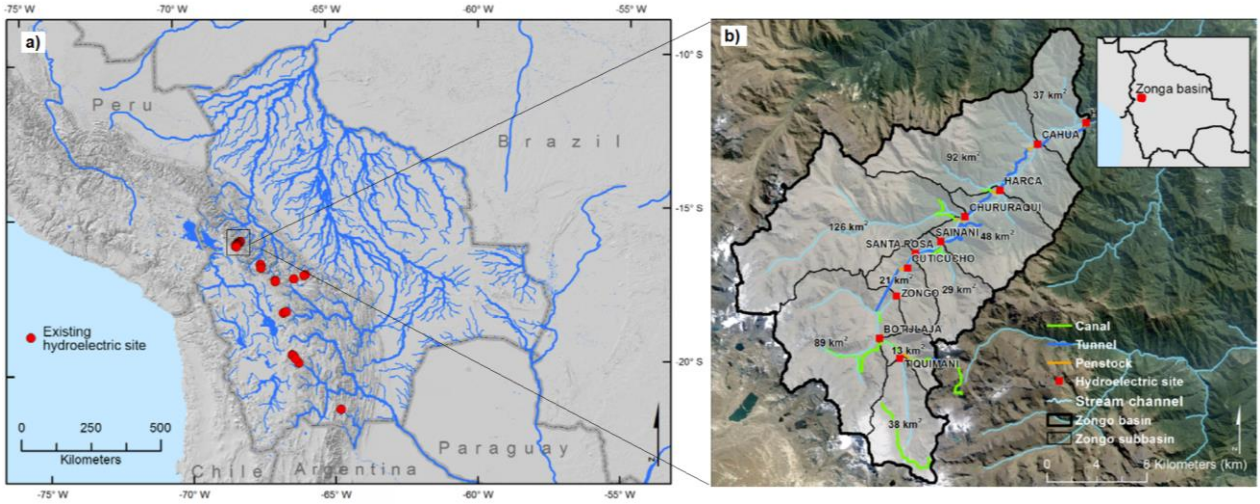

Fig. 4. a) Map showing the existing hydropower plans in Bolivia. b) Zongo cascade system, composed of small hydropower plants (located towards the north of La Paz city). Modified from Velpuri et al. (2016).

Micro and small hydropower plants are mainly located in isolated and dispersed rural areas. Most of the isolated rural areas are far from the national grid, hence the generation of electricity through small/micro hydropower plants is the most efficient energy solution for these areas. In Bolivia the small hydropower plants are up to 5 MW, however within the HYPOSO project the standard definition is up to 10 MW. Below a classification of the hydropower plants sizes in Bolivia:

- Micro: P < 500 kW
- Small: 500 kW < P < 5 MW
- Medium: 5 MW < P < 30 MW

Although in Bolivia most of the hydropower plants are labelled as medium or large, there are some regions with small and/or micro hydropower plants. The mining industry was the first sector in using micro hydropower plants for supplying energy for their camps and activities. In the mid of the last century, larger systems of small hydropower plants were built in the subAndean regions of La Paz (i.e. Zongo and Miguillas systems), refer to Fig. 4.b.

As mentioned before, the national government plans to develop and boost the hydroelectric sector, where the strategic plan includes small hydropower projects of approximately 30 MW which will be connected to the national grid. Hydropower plants with less than 20 MW of generation will be aimed for isolated networks. The identification of new small and micro hydropower plants is in progress.

To our knowledge there are about 10 active companies related to the medium/small hydropower sector in Bolivia (Punys et al., 2020). This small number of companies limit the development of projects within the hydropower sector. It is needed to have a wider option of companies (e.g. equipment manufacturing industry) that can offer, explain and train about their products in terms of, small turbines, penstock, electrical boards and other equipment needed in a hydropower project.

4. Research needs in the hydropower sector

As mentioned in the previous section there are few companies related to the hydropower sector. For instance, Ingelec, a Bolivian company, operated for many years in the construction, equipment, and installation of transmission/distribution lines of hydropower and thermal plants. However, this companies stooped their activities mainly due to the fact that specialized personal is not available in Bolivia. The aforementioned example reflects the current situation in Bolivia bout the hydropower sector: need of research, training of personnel and investment of resources in this sector.

About the training and research there are only two academic institutions that somehow are involved in the hydropower sector:

- Laboratorio de Hidraulica (Hydraulics Lab) is a research unit of Universidad Mayor de San Simon (Cochabamba). They have wide experience in numerical modelling of river flow and hydropower operation for more than 30 years. They also have experience in constructing scale models of hydropower plants for assessing their operation.
- Instituto de Hidraulica e Hidrologia (Institute for Hydraulics and Hydrology) is a research unit of the Universidad Mayor de San Andres (La Paz). They have experience in micro hydro technology and have been conducting research on it for more than 30 years.

The report of HYPOSO (Punys et al., 2020) identified about 19 research and development projects related to the hydropower sector. These projects were conducted between 2011 and 2019. Five of them are dealing with large hydropower plants. The majority of the identified projects were elaborated by universities. No novelty or fundamental research have been identified, therefore all the identified projects were study cases, application of well know methodologies. Moreover, the HYPOSO project elaborated a list of possible research topics to be developed in the near future:

- Studies about hydrology, including the analysis of short- and long-term climate change effects.
- Assessment of (multi-purpose) projects for hydroelectric industry perspective.
- Evaluation of the current state of micro and small hydropower plants, with the assessment of their operability and efficiency.
- Studies to increase efficiency in hydroelectric power
- Studies of new technologies that allow the maintenance of the facilities with minimal outages.
- Improvement in home electrical connection systems in the rural area.
- Hydropower socio-environmental and economic impact studies.

Regarding small hydropower plants there are some limitations that constrain their study, research and development of projects. The most important factor is that the national government prefers the development of large hydropower schemes located in the amazon basin, close to the border with Brazil. Also the policies, rules and conditions (e.g. low energy prices) for implementing renewable energy projects are not clear or they are not attractive for investors.

5. Conclusions

Bolivia is a country with a high potential for generating electricity through the hydropower development (either micro, small, medium or large schemes). The topography and water resources available are strategic aspects for identifying suitable locations for hydropower plants. Although the high potential of Bolivia for locating new sites for hydropower plants, there are several aspects to be solved or mitigate in order to achieve a full development of this sector. There are restrictions about data access, especially regarding hydrological data, but now the national surface water balance elaborated in 2018 is a good source of data. On the other hand, it is needed to encourage the link between private companies (i.e. equipment manufacturing and/or distribution within the hydropower sector) and local institutions (e.g. national government, universities and local companies), since there are very few companies in Bolivia that offers services or equipment for hydropower projects. Finally, it is needed to improve the organizational structures and financing mechanisms for encouraging the development of hydropower projects.

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