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Energy transitions and emerging economies: A multi-criteria analysis of policy options for hydropower surplus utilization in Paraguay

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ABSTRACT

In the context of increasing global efforts to migrate towards more sustainable energy systems, Paraguay is notable for boosting a power system based entirely on renewable sources. Paradoxically it has one of the lowest rates of electricity consumption in Latin America. Hence, a carefully crafted energy transition policy aimed at maximizing its energy resources could be the cornerstone of the country's long-term development strategy. The process of crafting public policy, particularly for emerging countries, entails an intricate decision problem involving several policy options with the potential to influence the country's welfare and all dimensions of socio-economic development. Thus, we present a policy-making tool applied to the multi-criteria decision energy policy problem in Paraguay, based on an Analytic Hierarchy Process model, which can aid in the crafting of more nuanced decisions. Here, four policy options are considered based on economic, technical, social, environmental and political criteria. Our findings are significant for the on-going policy debate on the "surplus question" in Paraguay and suggest that, considering the model employed, a policy oriented at directing the surplus to leverage the industrial cluster development is the best option. Additionally, we believe the proposed model could benefit other emerging economies for addressing similar policy dilemmas.

1. Introduction

Because of the need to migrate to increasingly renewable and cleaner energy systems on the face of the widely acknowledged non-sustainability of the global energy systems, countries all over the world have been increasing their efforts to secure long-run energy security based on sustainable energy sources. Among the tasks which must be addressed to attain these goals, are the energy mixes' diversification to reduce the systems' vulnerability, and the improvement of the employment of existing energetic resources to maximize their utility. To effect these tasks, governance and decision-making processes at government level play a prominent role (Markard et al., 2012). While the call for an Energy Transition is a global issue, the task of re-steering national policies to achieve the necessary transformations rests predominantly in the hands of domestic governments.

Paraguay presents an interesting case of study, highlighting a possible transition from an unsustainable biomass-burning running economy towards an increased use of the already available clean and sustainable electricity. The country's Energy Sector is a very particular case amongst other emerging economies. For instance, given the sharp divergence between its hydropower installed capacity and the average electric consumption Paraguay is one of the largest per capita hydroelectric power generators in the world, getting its energy from hydroelectric plants built in association with Brazil (Itaipu) and Argentina (Yacyreta) holding a 50% share in each project. Itaipu has an installed capacity of 14000 MW, with an annual average production of 98,287 GWh and Yacyreta has an installed capacity of 3200 MW, with an annual average production of 20,867 GWh (Sauer et al., 2015); however, the country's consumption levels are very low. The World Bank estimates Paraguay's domestic consumption per capita at 1400 kWh/year, equivalent to one third of the consumption levels of Brazil and Chile (World Bank, 2014).

Furthermore, the country's indigenous primary energy production is based wholly on renewable energy sources: hydropower and biomass. In contrast, its consumption mix is made up primarily of fossil fuels (38%) -the transport sector being the largest user- and unsustainable biomass (44%) -used mainly by households for cooking and heating, and by the industry (Ministry of Public Works, 2015). Although it is one of the largest exporters of hydropower in the world, electricity makes barely 18% of its final consumption mix. The significant participation of unsustainable biomass -largely extracted from unmanaged forests, contributing to the country´s already high deforestation rates - and of imported fossil fuels, could be reverted by taking full advantage of its hydroelectricity surplus.

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The country's already existing large hydro power surplus opens up a real possibility to enable a transition towards a more sustainable energy system, provided that the solutions proposed by the policy makers are aligned with the goal of making the most out of the country's surplus hydropower for the benefit of the society. Hence, taking Paraguay as a case study, the goal of this paper is to contribute with the use of an AHP-based tool to support decision making in emerging and developing economies in the context of energy transitions.

In this work, we consider Paraguay's decision making problem by looking at four hypothetical policy options: Continue with the current situation by continuing to cede hydropower surplus to Brazil (continuing with the normal course of operation) (A1); Selling hydropower surplus at the Brazilian wholesale power market (A2); Installing an electro-intensive aluminum factory (A3), and; Incentivizing the development of small industrial parks with an accumulated electricity demand of 1100 MW (A4). To carry out the assessment, we present a multi-criteria decision analysis (MCDA), based on an Analytic Hierarchy Process (AHP) model under five criteria: economic, technical, social, environmental, and political feasibility. Even more, we posit that the use of MCDA/AHP in emerging economies can help by providing a more holistic and multilateral view to decision making processes and allow a more balanced approach to energy policy making.

This paper is organized as follows. After a short background on the country's energy issues, a brief account of state-of-the-art literature on Energy Transitions and decision making in public policy is made in the next subsection. In Section 2, we present the methods MCDA and AHP in general and, later, in the specific case of energy planning. In this vein, we propose a specific methodology for fitting the energy problem space in Paraguay. The scenarios are introduced and we describe the criteria chosen and their indicators. In Section 3, we show the results and discussion of our analysis, including the sensitivity analysis of the model. In Section 4, the conclusions and policy implications of our work are presented.

1.1. Country background and energy issues

Unique features make Paraguay worthy of closer attention as a subject of study for the relatively straightforward and almost immediately visible benefits it could derive from an energy transition. Macroeconomically, Paraguay has made significant progress in fiscal and monetary aspects, and with the onset of major social reforms (World Bank, 2014) with a GDP which has been growing steadily, having reached its peak in 2013, when the GDP expanded to 13.6% —highest rate of growth in Latin America in that year. On a similar note, the American investor service Moody's upgraded Paraguay's government bond rating to B(A1) from B(A2), and changed the Paraguayan outlook to stable from positive (Moody's Investor Services, 2015).

As already described above, Paraguay's Energy Sector is characterized by the high disparity between its hydropower capacity and electric consumption. The country has a very large hydroelectric power potential per capita. With a population of around seven million people, it has been estimated to have the resources to produce 68 TWh/year of hydroelectric power, of which 64 TWh/year are thought to be economically exploitable (Toledano and Maennling, 2013). For instance, the generated electricity in 2011 was ~55 TWh and the domestic electricity demand ~7.5 TWh —barely 13% of the generated electricity (Toledano and Maennling, 2013).

The main source of surplus is the Itaipu Dam, built as a binational project since 1973 on the basis of a treaty between Paraguay and Brazil for the development and exploitation of Parana River's hydroelectric potential. The Itaipu Dam alone produces about 90,000 GWh/year, of which 50% correspond to Paraguay. Since Paraguay only consumes about 10% of its total share (Amarilla et al., 2015), the hydropower surplus of its share is ceded to Brazil in exchange for a fixed monetary compensation in accordance with the Treaty which stipulates that the surplus not consumed by one of the parties, in this case Paraguay, shall be transferred to the other contracting party, Brazil, limiting the chance to sell the energy to third-parties. Annex C of the treaty containing this provision is due to be revised in 2023.

Despite of being one of the largest exporters of hydroelectric power in the world, almost half of its domestic energy consumption is made up of biomass with a 44% participation of this energy carrier. Additionally, more than a third of its energy consumption basket corresponds to oil fuels at 38% (MOPC, 2015; Amarilla et al., 2015) while electricity, its second top export (Center for International Development at Harvard University, 2016), constitutes barely around 18% of its final energy demand. Not taking full advantage of its electricity surplus, plus the significant participation of non-sustainable biomass and oil-based energy sources is a clear imbalance detrimental to the country's energy security, the environment and the population's quality of life therefore touching upon all fronts: social, economic, and environmental.

On a positive note, the country's already existing large hydropower surplus opens up a real possibility to make feasible an energy transition with *relative ease* through the redirection of the country's Energy Policy guided by a willful decision to encourage the spread of hydropower in its energy consumption basket. Fostering increased consumption of indigenous hydroelectricity entails encouraging a transition from other less sustainable energy sources and an increased use of modern energy sources, such as electricity as opposed to unsustainable biomass and imported fossil fuels. Moreover, it could benefit the population and mitigate negative environmental impacts while reducing the biomass and oil dependency of the energy sector and therefore improving its balance of payment and energy security. In this sense, a hydropower based Energy Transition must constitute the cornerstone of Paraguay's development by supporting and accompanying the consolidation of the important economic growth the country has been displaying in the past years.

1.1.1. Policy debate surrounding "the surplus question"

As awareness on the existence of large hydropower surplus and the *hydroelectricity sovereignty* discourse became widespread among the general public after 2009 (Folch, 2015), discussions regarding the renegotiation of the bi-national treaties as well as on how best to employ the power surplus for society's overall welfare have been going on since then. In 2011, former president Fernando Lugo, during his administration, started pre-negotiations for the potential installation of an energy-intensive aluminum smelter by Rio Tinto Alcan (RTA)which proposed the production of 670000 MT of aluminum a year, with a yearly projected consumption of 1100 MW.[1]

Following these events, two reports were written at the Government's request on the assessment of the installation of RTA in Paraguay and other alternatives for the utilization of the hydropower surplus. The first report was written by London based CRU Strategies Ltd, and recommended either the installation of RTA starting in 2016 or to continue ceding hydroelectricity to Brazil (MIC, 2011; Congreso Nacional-Sala Bicameral, 2011). Two years later, Jeffrey Sachs' lead Columbia Center on Sustainable Development —formerly Vale Columbia Center on Sustainable Development— issued a second report, hereafter referred to as the "Sachs Report" recommending to sell the electricity surplus to the regional market and to use the financial resources in order to invest in the country's infrastructure and health system, advising against the installation of RTA's aluminum smelter (Toledano and Maennling, 2013).

Neither of the reports provided a complete analysis taking full account of all relevant aspects. For instance, during the Public Hearings, it was established that CRU´s Analysis was on a Cost-

[1] Compare to a peak demand of 3.026MW registered in February 2017.