

Original Paper

Cross-Boundary Energy-Resources Assessment for an Integrated Sources Harnessing and Sustainable Development

Vinícius Oliveira da Silva¹, Miguel Edgar Morales Udaeta¹, André Luiz Veiga Gimenes², Jose Aquiles Baesso Grimoni²

¹ GEPEA/EPUSP - Energy Group of the Department of Energy and Electrical Automation Engineering of the Polytechnic School of University of Sao Paulo, Brazil

² PEA-Department of Energy and Electrical Automation Engineering of the Polytechnic School of University of Sao Paulo, Brazil

Received: September 1, 2018 Accepted: October 8, 2018 Online Published: November 1, 2018

doi:10.22158/ees.v1n1p18

URL: <http://dx.doi.org/10.22158/ees.v1n1p18>

Abstract

The objective of this study is to evaluate the energy resources (ER) and the regulatory framework of the South American countries aiming at the sustainable development and to develop the South America Energy Integration (SAEI) in the long term focusing on structures such as transmission lines and pipelines. The methodology is based on the IERP (Integrated Energy-Resources Planning) and the analysis of the EI existing in South America. As result, the regulatory assessment provided evidence that the current structure is already in place with binational hydroelectric plants and transnational pipelines that promote energy integration. On the other hand, SAIE still needs an institutional evolution that gives more integration and quicker solutions to international arbitration. Finally, the construction of the attributes and sub-attributes and their respective valuations aiming at a SAEI strategy is not trivial, there is a need for the complete assessment of all the attributes and sub-attributes of the four dimensions established in the IERP methodology of the expansion of the SSERs analyzed to provide a strategy for the SAEI.

Keywords

energy planning, Integrated Energy Resources Planning (IRP), Energy Integration (IE), South America

1. Introduction

Despite the economic integration process—and energy—have started in Europe, related discussions have spread throughout the world, leading initiatives in other continents, including in South America (SA) (Reis, 2014). From the second half of the twentieth century were mechanisms developed in the

area of economic integration, the creation of the Union of South American Nations (UNASUL), the Southern Common Market (MERCOSUL) and Andean Community of Nations (CAN), plus others bilateral and multilateral initiatives aimed to the use of shared energy resources (ES) or trade them (Reis, 2014; Udaeta, da Silva, Galvão & de Souza, 2016; de Abreu, 2015).

In the last century it has been noticed an important increase of the energy projects on the SA, hugely associated with the Initiative for the Integration of Regional Infrastructure in South America (IIRSA) resulting in economic growth in the region, which in turn impacted on the increase of energy demand (Udaeta, da Silva, Galvão, & de Souza, 2016). Indeed, studies of the the World Energy Council (WEC) (WEC, 2004) and International Energy Agency (IEA) (IEA, 2010), proved that the energy demand (ENERDATA, 2012) of developing countries have increased due to the considerable growth of their economies (IMF, 2012), so much so that the title of the Human Development Report 2013 drawn up by United Nations Development Program (UNDP) was The Rise of the South: Human Progress in a Diverse World (UNDP, 2013). This report calls for new institutions which can facilitate regional integration and South–South cooperation and they are already sources of innovative social and economic policies, and increasingly development cooperation partners for other developing countries.

The development of the countries involves the access to energy resources and in turn this is linked to long-term energy planning. Since they are disproportionately distributed around the world, access to them is the question of disputes filed by various interests, being a matter of great geopolitical importance to a state. The access to ES involves different varieties of interests between countries that can be conflicting. Thus, a reasonable alternative, it is considered that policies aimed at energy integration (EI) can meet interests involved (Reis, 2014; Udaeta, da Silva, Galvão, & de Souza, 2016).

The essential idea of the EI is noted the contribution that energy and economic sectors in each country can the economic and social development process, within the framework of regional integration (UNDP, 2013; Udaeta, Burani, Fagá & Oliva, 2006). EI between regions and countries is fundamental to allow access to these sources, either through the direct transport of fossil fuels or biomass, through the sharing of hydroelectric power plants in border rivers or, indirectly, through the construction of transmission lines that power from the generation point to other consumer markets.

By enabling the commercialization of ERs or electricity itself, based on bilateral or multilateral agreements, EI can provide a reliable and efficient supply to huge energy consumers, also bringing economic gains for countries that sell their ERs and its surplus electricity (Suárez, 2006; Calogeras, Silva, Grimoni, & Udaeta, 2016). In the long term, is optimized energy generation, while taking advantage of the diversity resulting from connection to ES from neighboring countries, eliminating the dependence on a single energy source and reducing supply costs. Also, the creation of economic blocs and energy strengthens the integrated region, leveraging the political, commercial, social and cultural relations between its members (Reis, 2014; Calogeras, Silva, Grimoni, & Udaeta, 2016). Additionally, despite the potential benefits related to cross-border EI, there are many elements that hinder their achievement, they order being technical, environmental, political and economic.

In this sense, the objective of the paper is to evaluate the ESs and the regulatory framework of the South American countries aiming at the sustainable development and to develop the regional energy integration in the long term focusing on structures such as transmission lines and pipelines. Therefore, the work is divided in four more items, the first one being the analysis of the energy integration existing in South America (supranational organisms and infrastructures), followed by the description of the methodology of evaluation of the first and second-degree ESs that allow the energy integration in the long run and, finally, the results and analyzes of the study and its final considerations are presented.

2. Energy Integration in South America

The main difficulties, associated with the implementation of integration projects, refers to the articulation of rules and congruent with the incentive to investment and energy interdependence policies. It comprises several aims, agreements and regulations that involve complex legal issues facing opening markets and thereby enabling the creation of rules to facilitate equity transactions and investments, whether they are state, private, national or multinational. This process involves internal political issues of the countries related to the acceptance and approval of laws and internal projects involving diverse interests within the nation, in addition to elements associated with the foreign policy of each state and its geopolitical interests in the region (Reis, 2014; Udaeta, da Silva, Galvão, & de Souza, 2016; de Abreu, 2015).

About differences of interests among SA countries case, one can use the question as an example of the suspension of the supply of natural gas through the cross-border gas pipelines from Argentina to Chile, this suspicion occurred even though there were contracts signed between the companies of both countries and the interruption of UTE Uruguiana (639 MW) from 2009 to 2014 due to lack of gas in Argentina (Faria, Silva, Udaeta, Abreu, Gimenes, & Grimoni, 2016) or also the Bolivian gas, in which Bolivia nationalized refineries belonging to Petrobras, claiming that the contracts had been established the wounded interests of the Bolivian nation (Antunes, 2007).

These cases demonstrate that the larger the number of agents involved in the process, the greater the effort in establishing policies of interest to everyone. That is why the most fruitful experiments were those made them bilaterally arising from projects with strong participation of national states.

From a technical standpoint, the interconnections require an infrastructure with bi-reaching or multi goals, that includes all involved and interested. So that the integration process is done in a cohesive manner, it is essential to studies that provide adequate planning be made, about the energy generation, transmission and distribution (G-T-D), as well as the interests and economic returns for the various agents involved in the issue. The greater the need for infrastructure and technical complexity related to the projects become more expensive the same—which implies the need for large investments of money and, most often, in various financing. In the case of SA, the infrastructure integration projects to sizable proportions by both distances, as the natural difficulties imposed by the environment.

2.1 History of the South American Energy Integration Process

The process of South American energy integration (SAEI) starts from the mid-twentieth century, by means of natural gas, having two axes of the main action, oriented from the actions of the MERCOSUL and CAN (Udaeta, da Silva, Galvão, & de Souza, 2016; Antunes, 2007). It should be noted that these economic blocks have economic complementation agreements among themselves and with Chile, that is not a member of both. The process of Elarisen in the XX-XXI century and it can be separated into three stages (Reis, 2014):

- i. First period, the 1970-1980s, was marked by a great performance of National States in building binational projects, such as the hydroelectric power plants of Itaipu (Brazil/Paraguay), Salto Grande (Argentina-Uruguay) and Yacyretá (Paraguay/Argentina), and transmission lines associated with these binational power plants.
- ii. Second period occurred after the end of the 1980s. It was marked by political economic liberal reforms, resulting in decreased performance of states and the increased of the private participation in the SA country's economy. Thus, it has begun the implementation of projects with varying degrees of participation of public, private and mixed enterprises, involving mainly the gas and oil sector. Many binational pipelines have been constructed, demonstrating the importance of this resource within the SAEI. Even with the differences involving the form of state action. Indeed, it is noticed that projects were limited to the bilateral framework, demonstrating the nonappearance of a regional integration policy.
- iii. Third period, occurred in the XXI century, it is turned is linked to the economic and political changes on the SA. Initially, with the election of presidents of the Left parties made to gather strength in the region's anti-imperialist and anti-liberal discourse, changing the financing projects logic and strengthening the participation of States in the economies again. Meanwhile, economic growth achieved by countries of region, especially Brazil, resulted in an increase in its energy demand. With this, the 1st decade of XXI century, there was a propensity to transform this idea bilaterally (first period) to give a more regional and multilateral character to integration projects. In this context that was shaped in 2000, the Initiative for the Integration of Regional Infrastructure in South America (IIRSA), in order to promote the interconnection of telecommunications, energy, transmissions lines and gas & oil pipelines (Udaeta, da Silva, Galvão, & de Souza, 2016; Oxilia, 2009).

With the IIRSA's project and with financing from institutions such as the World Bank (WB), Inter-American Development Bank (IDB), Financial Fund for the Development of Prata Basin (FONPLATA) and the Andean Development Corporation (CAF), it was intended to establish conditions to the development of trade agreements and EI. Thus was deposited confidence in the achievement of IIRSA, despite the logical difficulties inherent to their achievement, such as disparity markets, privilege certain actors, history of binational conflicts and difficulty of regulatory consistency between countries (Udaeta, Burani, Fagá, & Oliva, 2006). In 2009, IIRSA has been discontinued and its projects were

linked to the South American Council of Infrastructure and Planning (COSIPLAN) linked to the UNASUL (COSIPLAN, 2013). Also, the COSIPLAN along with UNASUL, retains the idea of strengthening multilateral relations in SA, to give greater political support infrastructure integration projects (Udaeta, da Silva, Galvão, & de Souza, 2016).

2.2 Southern Common Market

Created in 1991, the MERCOSUL consisting of Brazil, Argentina, Paraguay, Uruguay and Venezuela (MERCOSUL, 2016). Despite the conception of this economic bloc has been linked to the need for expansion of internal markets and stimulate the circulation of goods and services in the region, without being tied directly to the energy issue, there were already binational relations among its members.

Since the formation of MERCOSUL, the energy sector showed considerable changes. Among them stand out the reform of the state roles, that acting more as a regulator than as an entrepreneur, and consolidation of natural gas (NG) as an integrating feature of the region. All countries in the region have construction pipelines (Udaeta, Burani, Fagá, & Oliva, 2006).

Among the binational projects of power generation worth mentioning the construction of Salto Grande, Itaipu and Yacyretá power plants, and the Central Salta, a combined cycle power station, built by a Chilean company to generate electricity from Argentina's GN, but not providing energy for this country. In the case of Itaipu, aiming harness the hydroelectric potential of the Paraná River, Brazil was responsible for the investments and setup project the construction of the power plant. In addition, to financing the part that would fit Paraguay (Oxilia, 2009; Oxília & Fagá, 2006).

2.3 Andean Community of Nations Region

Created in final of 60's, the CAN is formed by Bolivia, Colombia, Ecuador and Peru. The region covered by the CAN has a huge potential energy, both in terms of hydrocarbons (gas & oil), as regarding the hydro, among others. About the oil market, Colombia, Ecuador and Venezuela are configured as suppliers to countries like Brazil, Chile and Peru, since they have oil consumption that exceeds their production. In contrast, with Bolivia and Venezuela that have resources that exceed their local demands. It is important highlight the Chile's situation, that due to its lack of ESs, is much interested in integration projects that allow the supply of its internal energy demand.

Castro (Castro, Dassie, & Delgado, 2009) says that the process of EI in the CAN began in 1969 with the construction of the Zulia-La Fria transmission line, connecting Colombia and Venezuela. the authors claim that this project was the first step for the EI occurred in the region. Besides that, it state that the evolution of the process of electrical interconnection between the Andean countries has enabled advances, such as the prediction of building an interconnection between Bolivia and SIEPAC. Udaeta et al. (Udaeta, Burani, Fagá, & Oliva, 2006) also highlight the role of interconnections in the integration process in CAN, noting that Bolivia appears as a "hinge", because of its possibilities of interconnection with Brazil, Chile, Argentina and Peru.

Besides the physical integration, it cannot overlook the advances that have happened in legal and political terms to permit the access to transmission lines between countries. Thanks to that, better

prospects around integration projects in the region. Even so, it is of great technical, economic, political and complexity to implementation of transnational projects. So that the more countries involved, and the larger the area covered, the greater the effort. Antunes (Antunes, 2007) cites the proposal for EI taken by Chile in 2007, and that would involve this country along with Ecuador, Bolivia, Colombia and Peru, based on an CAN multilateral agreement aimed at prevent interference geopolitical discussions on exit to the sea for Bolivia lost.

2.4 South America Energy Integration Projects

Clearly, it cannot reduce the process SAEI only to economic blocs in the region. In this sense, the conception of IIRSA, and after the COSIPLAN makes integration projects that go beyond the limits of economic blocs, giving greater geopolitical consistency to the region are fortified. The initiative has certain principles involving the approach between the countries that are based on open regionalism, contemplating the need to minimize internal barriers to commerce, bottlenecks in infrastructure and regulatory systems and operation, in the Integration and Development Axis (IDA), that is organized into 10 axes (Andean, Amazon, Peru-Brazil-Bolivia, Capricorn, Guyanese Shield, South Andean, Central Interoceanic, MERCOSUR-Chile, Parana-Paraguay Waterway and South) (Udaeta, da Silva, Galvão, & de Souza, 2016; Oxilia, 2009) regions was taken, clearly transcending the boundaries of economic blocs.

Throughout its existence, IIRSA and currently the COSIPLAN, developed important projects, with a portfolio of 579 projects in study (23.5%), pre-running (28.8%), running (29.2%) and completed (18.5%), with an approximate investment of US\$ 163.069 billion (IIRSA, 2016). According to the COSIPLANs projects portfolio (COSIPLAN, 2013), the energy sector concentrated 59 projects, of which 27 (46% of the total) are aimed at generating, representing 75% of the total investment, and 32 inter connections projects. These projects receive investment especially from public/private partnerships (68% of total investments) followed by the public sector (25%); this characteristic is due to the high value of the individual projects and the fact that they are structuring, with market opening bias, creating conditions for businesses and society to have access to new regions and can dispose their productions. Projects in the energy sector are mainly based on the construction of new interconnections, 52.5% of the total projects and 25.1% of investments. Hydroelectric plants, because they are characterized as large enterprises of electricity generation, hold 27.1% of the projects portfolio and 63.8% of investments.

By analyzing these data, IIRSA fostered a development that is organized much like physical interconnection than actual integration. This phenomenon is related to building a highway network connecting the Atlantic and Pacific interests, to foster the flow of goods across the SA (Reis, 2014). Gudynas (Gudynas, 2008) inquiries the interests that were behind the IIRSA project by privileging the physical interconnections and seek not intrinsic to strengthen other aspects integration process such as productive, political and cultural ties. Other limitations are associated to IIRSA the lack of progress in the sectorial policies harmonization, relevant regulations and tiny consideration given an environmental

and social aspects.

About the pursuit of multilateralism in the SAEI process, it should be noted the role of Bolivia, which has a role of coordination between of the Southern Cone and the CAN countries. Being a country with huge NG reserves and it has low power consumption. Bolivia is shaping up as a major supplier of NG resource to importing countries, such as Argentina, Brazil and Chile. i.e., the Bolivia-Brazil pipeline, a major milestone of the SAEI, due the importance of consolidating NG chain in the Brazilian energy matrix (Reis, 2014).

EI also consolidates Brazil as a major buyer of energy. Despite having huge reserves of ESs, it has shown a significant increase in its demand. Consequently, the Brazilian government has increasingly sought to stimulate energy ventures outside its territory. In addition, to seek for satisfy its energy demand, there is a clear interest in encouraging the sharing of Brazilian capital on projects through funding from its national bank, named National Bank for Economic and Social Development (BNDES) and the participation of Brazilian construction companies civil (Udaeta, Burani, Fagá, & Oliva, 2006).

In this context, in 2009 Brazil and Peru was signed by both countries an agreement for the construction of six hydroelectric plants—Inambari (2,000 MW), Sumabeni (1,740 MW), Paquitzapango (2000 MW), Urubamba (940 MW), Vizcatán (750 MW) and Cuquipampa (800 MW) together these plants would total approximately 9,000 MW of installed capacity (ELETROBÁS, 2013) to supply the energy to both countries and situated in the Amazon basin of Peru's territory. Due to the position where it will be deployed, covering areas of huge biodiversity and where local communities, projects of this nature are carried live by controversy due to contradictions involving their economic gains and environmental impacts they generate. In fact, despite these initiatives have targeted to meet economic interests in the area, their environmental and social impacts are left in the background.

3. Integrated Energy Resources Planning (IERP)

The energy planning often has as priorities the energy supply and GDP increase in the short term and, eventually, medium term. This traditional planning is concerned exclusively with the difference between the forecast energy demand and the prediction of supply. Hence, the amount of energy needed in the short and medium term is determined and the options that present lower cost of installation, maintenance and operation are identified. Thus, traditional energy planning foregrounds the technical and economic aspects at the expense of environmental and social aspects (ELETROBÁS, 2013; Udaeta, 1997; Udaeta, 2012; Grimoni, Galvão, Udaeta, & Kanayma, 2015).

As the Integrated Energy Resources Planning (IERP) meets the need for a more complete and comprehensive planning when compared to the traditional planning, its main function is to be a tool for energy planning in the short, medium and long term, in which various ESs, viewpoints and aspects are considered (Udaeta 1997). However, there are evidences that the energy sector adapts too slowly to this model of energy planning (Grimoni, Galvão, Udaeta, & Kanayma, 2015). Besides that, the IERP differs from the traditional planning in one main aspect, i.e., the insertion of stakeholders in the planning

process, from the policy maker to the ES user (Udaeta, 2012). The IERP is the process through which a group of alternatives, both on demand and supply sides, are planned, implemented and evaluated based on at the costs that balance the groups interest (Cicone, 2008).

The goal constantly pursued by IERP is the determination of the portfolios of ESs at the lowest full cost; and, the traditional ways of calculations fail to consider all the elements present in such analysis. Besides, the pressure exerted by various members of the society can often causes a great project financial evaluation to be unviable, generating waste of time and money to those who believed and invested in energy project, since many measurement systems lacked strategy alignment, a balanced approach and systemic thinking, they had difficulty in systematically identifying the most appropriate metrics (ELETROBÁS, 2013; Udaeta, 2012; Udaeta, Galvão, Rigolin, & Bernal, 2016). In the IERP the participation of society is called Engaged-Stakeholders (En-St). This detailing and deep stratification of ESs allow the decision maker to have grants that will help in selecting the next investment, i.e., impacts, benefits and risks are clearer than in many traditional planning (Gimenes, 2004).

Linked to this, the fact that the IERP examines the Energy Planning in the long term, it assists entities in having several use scenarios for 20 and 30 years or more. Also, in its full form, the IERP can provide organizations with a framework to visualize how these scenarios will be modified according to the short-term choices. In this sense, the IERP (Cicone, 2008; Gimenes, 2004; Udaeta, Gimenes, Galvão, & Fujii, 2004), i.e., IERP, places the sustainable development as its most diffuse goal.

Thus, to use sustainable energy in general and for IERP it is necessary to compare each one Supply-Side Energy Resources (SSER) and each one Demand-Side Energy Resources (DSER) in a way to generate the listing, screening and selection of ESs for later create the ranking of ESs, organized from the most indicated to the least indicated to be applied for instance, the ranking is only a reference for the next steps of IERP (Gimenes, 2004). It is worth mentioning that one of the basic premises of the IERP is not to discard any ES. A resource that is not available or is not of immediate interest can be included, for example, five or ten years ahead, as the IERP is a long-term energy planning, which should include scenarios that incorporate effects on the society (ELETROBÁS, 2013; Udaeta, 1997; Grimoni, Galvão, Udaeta & Kanayma, 2015; Gimenes, 2004; Baitelo, 2011).

The list of ESs aims to identify all resources that can be used throughout the planning horizon, regardless of technological characteristics or their acceptance, whether social or Market. Already the screening is simply the moment prior to selection and ranking, in which consideration for full assessment of some resources is suspended as determines methodologies and procedures within the IERP (Udaeta, 1997; Cicone, 2008; Baitelo, 2011).

About the Supply-Side Energy Resources (SSER), it is worth defining them as the composition of a primary source of energy linked to a particular technology of use (Cicone, 2008). Already the Demand-Side Energy Resources (DSER) are the technologies and/or actions that allow you to conserve or save energy. This energy, called “virtual generation”, is seen in the IERP as an ES because it allows

its use in other end-uses or even saves the energy source for later use. Nevertheless, it still postponing investments in the energy sector (Cicone, 2008).

Usually, this decision making is performed with technical and economic data. However, in the case of IERP are included other dimensions which participate with the same weight in the results. Among the technical-economic aspects are considered the environmental, social and political factors. It also evidence that the greatest difficulties of considering these types of impacts are subjectivity and difficulty in pricing (Udaeta, Galvão, Rigolin, & Bernal, 2016).

4. Methodology Elements

The methodology adopted for the characterization of SSER is based on the survey of the several existing technologies to produce energy through various sources, whether renewable or not, as well as their generators and their characteristics, and it is an adaptation based on the procedure described by Rigolin (Rigolin, 2013).

The essential step to the methodology is the determination of the decision tree, which consists of attributes, sub-attributes, ESs and its structure. From this tree, as stated in the IRP established methodology (Udaeta, 1997) the main dimensions cannot be modified, which are divided as follows: (i) Technical-economical; (ii) Environmental; (iii) Social; and (iv) Political, see Figure , and each of them has equivalent weights of 25%.

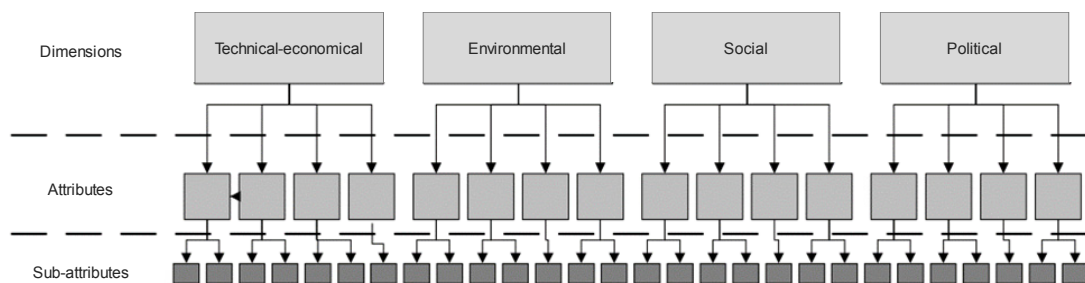


Figure 1. Hierarchical Tree Model Methodology for AHP (Rigolin, 2013)

The complete model for the IERP has about 50 attributes and sub-attributes (Baitelo, 2011) distributed in four dimensions. It is worth mentioning that the sub-attributes are customizable according to the applied IERP and, for verification of the model. After the construction of the decision tree, the ESs can be analyzed in accordance with all attributes and sub-attributes defined in the hierarchical tree (Udaeta, Galvão, Rigolin, & Bernal, 2016).

As evaluation is linked to long-term planning it is important to create scenarios of 20-30 years. The construction of this long-term planning horizon can have based on data such as GDP per capita, population growth, % of electricity coverage and basic sanitation, etc., it is possible to estimate the demand for electric energy, drinking water, sanitation and so on according to their usual growth. The total demand will be the sum of the repressed and usual demands in each case (Gimenes, 2004).

This study demonstrates the valuation of the Resource Property attribute, which analyzes the origin and ownership of energy sources, considering their local, regional or national availability and the extension of the use of resources through international agreements and energy integration measures, and their respective three sub-attributes linked to the political dimension: (i) ownership, property and energy integration, see Figure 2.

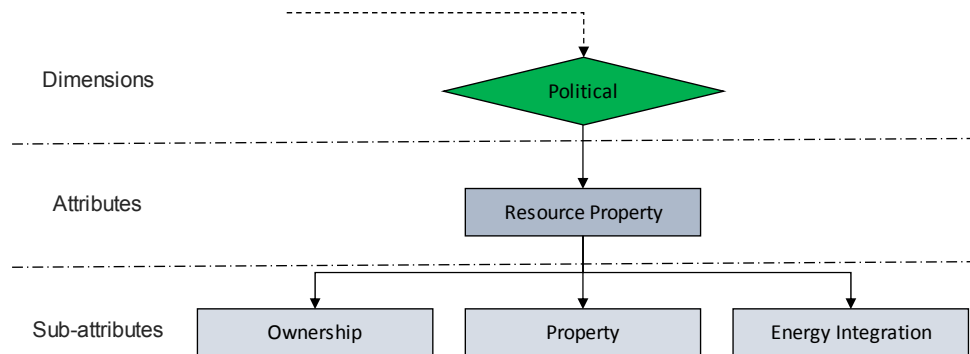


Figure 2. Hierarchical Tree Model of Attributes and Sub-Attributes Studied in the Political Dimension

The algorithms of valuation attributes of the possession and ownership of ESs and energy integration between regions are constructed together. The type of unit evaluated are qualitative and the conversion to standardization of this type of unit is by means of discretization (Rigolin, 2013), see Table 1. The possession of the energy source can be evaluated as: (i) free access (such as wind, solar and biomass); (ii) intended for multiple uses (water); (iii) owned by the Union or (iv) foreign (Baitelo, 2011). The location of energy sources can be measured in surveys of local, national and international databases, property and ownership of ESs can be researched in local and regional legal frameworks and energy integration agreements and commitments are constantly updated information by newspapers, journals or official publications of government agencies.

Table 1. Data Types Contained in the Political Dimension (Rigolin, 2013)

Attribute	Sub-attribute	Type of Unit / Unit	Conversion to Standardization
Resource Property	Ownership	Qualitative	Discretization
	Property	Qualitative	Discretization
	Energy Integration	Qualitative	Discretization

5. Energy Potential of South America

SA is a region rich in ESs, especially oil and water resources, various integration projects in terms of

energy already deployed or are in process in SA is worth mentioning that many of these features occur so border making it complex to operate and manage, highlighting the Andes and the Amazon River (Reis, 2014).

Andes is a large mountain range spanning five countries in SA, it is being a natural border, and constitutes a major mineral area in the world. The waters of the Amazon River account for much of the freshwater available in the world. This river initiates in Peru, crossing the border with Colombia until you reach the tri-border involving these two countries and Brazil. It is not by chance, these three countries are those with greater hydroelectric potential in SA, see Figure.

Analyzing the Figure, it is seen that the total hydropower potential of the SA is 590 GW, so that Brazil is by far the country with the greatest potential, exceeding 250 GW. It is no wonder that this country has the largest hydropower generation in the region (403 TWh in 2010), corresponding to 11.5% of the world's hydroelectric production (IEA, 2017). Likewise, it should be highlighted Venezuela, since this country occupies the 9th place ranking producer of hydroelectricity in the world and is the second largest SA [(IEA, 2017; OECD/IEA, 2012).

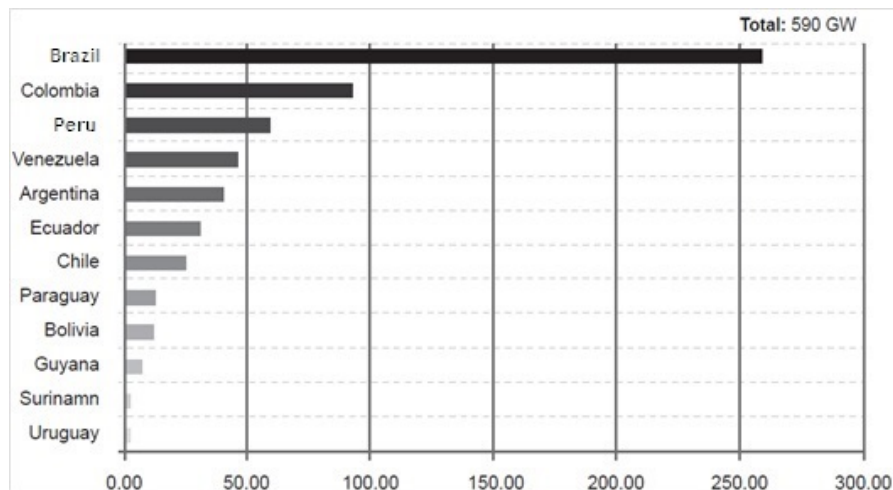


Figure 3. South American Hydroelectric Potential (Udaeta, da Silva, Galvão, & de Souza, 2016; OECD/IEA, 2012)

About hydrocarbons should be highlighted reserves of NG and oil on the continent. SA has about 4.2% of global NG proved reserves, so that the majority is in Venezuela with 6.4 Gm³, followed by Brazil and Peru with 0.4 Gm³ each one and, Argentina and Bolivia with 0.3 Gm³ each (BP, 2018), see Figurea. Oil cannot be overlooked when it comes to meeting the SA energy potential. The region has large proven reserves of this resource, with almost 19% of the total proved reserves, highlighting, once again, to Venezuelahas the largest proven oil reserves in the world with 303.2 billion barrels of oil (BP, 2018). Brazil and Ecuador also have significant reserves of 12.8 and 8.3 billion barrels of oil respectively, see Figureb.

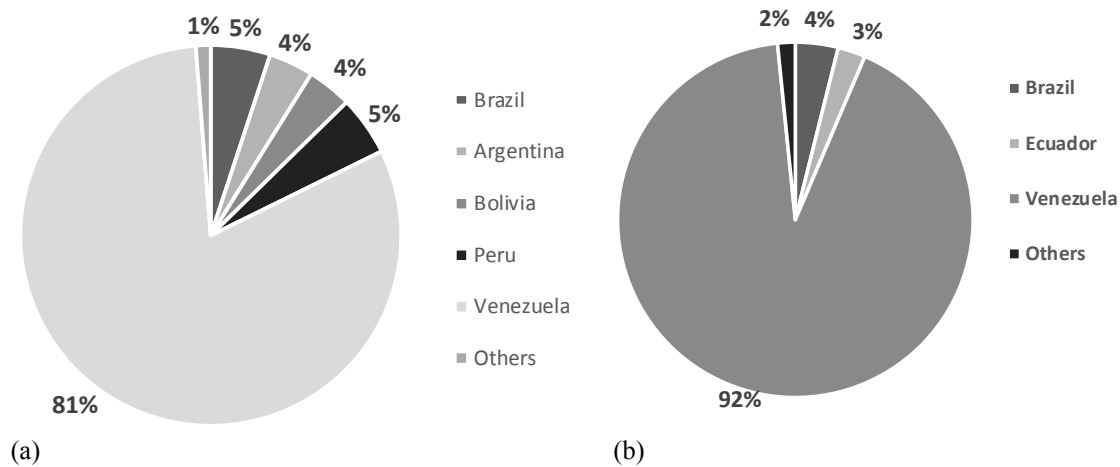


Figure 4. South America Distribution of Proven Reserves in 2017 (a) Natural Gas and (b) Oil

6. Construction of Attributes and Sub-attributes in South America Energy Integration

The Supply-Side Energy Resources (SSER) analyzed is Natural Gas (GN) linked to Bolivia's proved reserves and transported in Gasbol (Brazil-Bolivia Gas Pipeline) to Brazil. This choice is due to the great availability of the energy source and the possibility of exports in the long term. Following is the valuation of attributes and sub-attributes:

- Place of the energy source: it fits as a national source, in the case of Bolivia;
- Ownership: is of the Union according to the *Ley de Hidrocarburos (Ley N° 3058)* that establishes that the State will exercise, through the *Yacimientos Petrolíferos Fiscales Bolivianos (YPFB)*, its proprietary right over all hydrocarbons (BP, 2018);
- Property: state-owned and private companies established in five Brazilian states, which use the resource through national and imported technologies (BP, 2018; TBG, 2016), being the end-use to multipurpose (electricity, heat and etc);
- Integração Energética: long-term bilateral contract, 30 years, in the take-or-pay category, signed between the state companies of both countries, YPFB of Bolivia and Petrobras of Brazil. Being operated on the Transportadora Brasileira Gasoduto Bolívia-Brasil SA (TBG) and on the Bolivian side by Gás Transboliviano SA (GTB), both are subsidiaries of the state-owned companies of each country (TBG, 2016; Udaeta & da Silva, 2017).

7. Elements for Consideration

Likewise, ESs are not spread evenly around the world, so that trade in ESs and electricity can benefit both the importing and exporting country. Despite the difficulties involving EI as questions of sovereignty of countries and divergence of interests among En-St, the process of EI can take a lot of benefits for developing countries.

SA case shows that, in a context in which the process of economic integration is in a somewhat advanced stage, thus hampering EI. The transnational energy projects are restricted to bilaterally.

Showing that the process of SAEI was not an end, but a means to meet the energy and economic needs of certain countries and agents in sure recent historical periods. In other words, projects such as Itaipu and Bolivia-Brazil NG Pipeline had as main aim to serve the economic interests of the parties involved and not EI itself.

Even in recent initiatives, such as IIRSA and now COSIPLAN, the EI sectors of the SA countries occurs in a larger plan. Infrastructure's integration, which also involves networks of movement and communication. Therefore, it means achieving a bigger integration project. Even so, COSIPLAN is the main initiative of SAEI in the beginning of the 21th century, in a context where projects occur beyond the traditional economic blocs.

The construction of the attributes and sub-attributes and their respective valuations aiming at a South American Energy Integration (SAEI) strategy is not trivial, since there is an intense need for databases and information from each analyzed region, be it a national or supranational state, for later systematization and evaluation.

Finally, there is a need for the complete assessment of all the attributes and sub-attributes of the four dimensions established in the IERP methodology of the expansion of the SSERs analyzed to provide a strategy for the SAEI.

References

- Antunes, J. C. (2007). *Infraestrutura na América do Sul: situação atual, necessidades e complementaridades possíveis com o Brasil*.
- Baitelo, R. L. (2011). *Modelo de Cômputo e Valoração de Potenciais Completos de Recursos Energéticos para o Planejamento Integrado de Recursos*. Escola Politécnica da Universidade de São Paulo.
- BP. (2018). *BP Statistical Review of World Energy 2018*. London.
- Calogeras, H., Silva, V. O., Grimoni, J. A. B., & Udaeta, M. E. M. (2016). Energy Productivity Estimation in the Economy of the Common Market of South America. *23rd World Energy Congress, I*, 869-883.
- Castro, N. J., Dassie, A. M., & Delgado, D. (2009). *Indicadores Mundiais do Setor Elétrico—As Experiências Latino-Americanas de Integração Energética*. Rio de Janeiro.
- Cicone, D. (2008). *Modelagem e Aplicação da Avaliação de Custos Completos através do Processo Analítico Hierárquico dentro do Planejamento Integrado de Recursos* (pp. 1-146). Dissertação—Esc. Politécnica da Univ. São Paulo. <https://doi.org/10.11606/D.3.2008.tde-08062009-164421>
- COSIPLAN. (2013). *Carreira de Proyectos 2013. IV Reunión Ordinária de Ministros del COSIPLAN*. Chile.
- de Abreu, A. C. (2015). *A Integração da Indústria de Energia Elétrica na América do Sul: Análise dos Modelos Técnicos e de Regulamentação*.

- dos Reis, A. G. (2014). *A arquitetura da integração energética sul-americana, a participação brasileira e a geoenergia humana*.
- ELETROBÁS. (2013). <http://www.eletrabras.com>
- ENERDATA. (2012). <http://www.enerdata.net>
- Faria, D. M. C., Silva, V. O., Udaeta, M. E. M., Abreu, A. C., Gimenes, A. L. V., & Grimoni, J. A. B. (2016). Power Deal of Canada & US Assessment Seeking a Brazilian Model for Energy Integration in South America. *23rd World Energy Congress*, 607-625.
- Gimenes, A. L. V. (2004). *Modelo de integração de recursos como instrumento para um planejamento energético sustentável*. Escola Politécnica da Universidade de São Paulo.
- Grimoni, J. A. B., Galvão, L. C. R., Udaeta, M. E. M., & Kanayma, P. H. (2015). *Iniciação a conceitos de sistemas energéticos para o desenvolvimento limpo* (2nd ed.). São Paulo: Edusp.
- Gudynas, E. (2008). As instituições financeiras e a integração na América do Sul. In R. Verdum (Ed.), *Financiamento e megaprojetos. Uma interpretação da dinâmica regional sul americana*. Brasília: Inesc.
- IEA. (2010). *World Energy Outlook 2010*. Paris.
- IEA. (2017). *Key World Energy statistics 2017*.
- IIRSA. (2016). Iniciativa para a Integração da Infraestrutura Regional Sul-Americana. Retrieved from <http://www.iirsa.org>
- IMF. (2012). *International Monetary Fund*. Retrieved from <http://www.imf.org>
- MERCOSUL. (2016). *Mercado Comum do Sul*. Retrieved from <http://www.mercosur.int>
- OECD/IEA. (2012). *Technology Roadmap. Hydropower*. Paris.
- Oxíliã, V. (2009). *Raízes Socioeconômicas da Integração Energética na América do Sul: análise dos projetos Itaipu Binacional, Gasbol e Gasandes*.
- Oxíliã, V., & Fagá, M. W. (2006). As motivações para a integração energética na América do Sul com base no gás natural. *Petro e Química*, 289, 70-74.
- Rigolin, P. H. da C. (2013). *Desenvolvimento de um sistema para classificar recursos energéticos de oferta e demanda com base no cômputo e na valoração do potencial completo dos recursos energéticos dentro do planejamento integrado de recursos energéticos*. Escola Politécnica da Universidade de São Paulo. <https://doi.org/10.11606/T.3.2013.tde-09072014-111702>
- Suárez, L. P. L. (2006). *O Papel das Petrolíferas para o Desenvolvimento da Integração Energética: A formação do Mercado de Gás Natural na América do Sul*. Unicamp.
- TBG. (2016). Shareholding composition. Retrieved from <http://www.tbg.com>
- Udaeta, A. G., da Silva, V. O., Galvão, L. C. R., & de Souza, F. N. (2016). Analysis of Energy Integration and the Transboundary Superstructure in South America. *J. Bus. Econ.*, 7(1), 21-43.
- Udaeta, M. E. M. (1997). *Planejamento Integrado de Recursos Energéticos—PIR—para o setor elétrico (pensando o desenvolvimento sustentável)*. Escola Politécnica da Universidade de São Paulo.

- Udaeta, M. E. M. (2012). *Novos Instrumentos de Planejamento Energético e o Desenvolvimento Sustentável—Planejamento Integrado de Recursos Energéticos na USP*. Universidade de São Paulo.
- Udaeta, M. E. M., & da Silva, V. O. (2017). *PEA5899* (p. 60).
- Udaeta, M. E. M., Burani, G. F., Fagá, M. T. W., & Oliva, C. R. R. (2006). Ponderação analítica para da integração energética na América do Sul. *Rev. Bras. Energ.*, *12*(12).
- Udaeta, M. E. M., Galvão, L. C. R., Rigolin, P. H. da C., & Bernal, J. L. de O. (2016). Full assessment energy-sources for inclusive energy-resources planning. *Renew. Sustain. Energy Rev.*, *66*, 190-206. <https://doi.org/10.1016/j.rser.2016.07.008>
- Udaeta, M. E. M., Gimenes, A. L. V., Galvão, L. C. R., & Fujii, R. J. (2004). *Elementos de Planejamento Integrado de Recursos Energéticos* (pp. 1463-1473).
- UNDP. (2013). *Human Development Report 2013—The Rise of the South: Human Progress in a Diverse World*. United Nations Development Programme (UNDP), New York.
- WEC. (2004). *Eficiência Energética: uma análise mundial*. Rio de Janeiro.