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Review

Evaluating Energy Policies through the Use of a Hybrid Quantitative Indicator-Based Approach: The Case of Mercosur

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Abstract: This paper evaluates the performance of energy policies in the Southern Common Market (Mercosur), a regional initiative consisting of Argentina, Brazil, Paraguay and Uruguay, but also considering Venezuela (full member since mid-2012) and Bolivia (full participation under negotiation since 2015). The methodology is based on a qualitative-quantitative approach. First, we provide a critical review of the literature on energy security. Then, we carry out a comparative analysis of energy policies in Mercosur countries, concluding that there is no harmonization between them. Next, we offer the new concept of socio-environmental-energy security (SEES) as a more suitable approach to deal with current challenges, providing a hybrid quantitative indicator-based approach to the SEES index. Ergo, after defining the indicators, selecting the data, carrying out a normalization process, assigning weights and aggregating data points, the SEES composite index is generated. We suggest that energy integration can contribute to better regional performance in terms of energy policies and that the SEES index can guide policy makers and investments, replacing the old-fashioned concept of energy security.

Keywords: energy security; energy indicators; developing countries; Mercosur

1. Introduction

As energy markets become increasingly global and interdependent, issues affecting energy systems also increase in number and complexity. Consequently, energy security in global markets is determined by many factors, such as economic growth, energy efficiency, pressure to reduce greenhouse gas (GHG) emissions, development and implementation of new technologies as well as the social role in ensuring (universal) access to energy.

The concept of energy security has raised controversies over its definition, scope and approaches for decades, mainly because it is a concept that emerged in the context of the 1970s international oil crises. Studies on energy security have been criticized for a number of reasons, including that they employ a narrow interpretation of the concept and rarely use a systematic approach. Significant differences between studies are observed in how energy security is evaluated qualitatively and/or quantitatively. The latter usually considers the assembly and use of indicators.

It is important to emphasize that Mercosur is a regional bloc that incorporates only a few countries from South America, not being a Latin American initiative per se. Thus, by Mercosur we refer to the joint initiative between Argentina, Brazil, Paraguay and Uruguay. In addition, it should be taken into account that Mercosur has been experiencing a very peculiar moment, not only because it celebrated its 25th anniversary in 2016, but also due to recent political changes. Examples of these political changes are the new political projects in Argentina and Brazil, as well as Mercosur's relations with Venezuela.

The growing energy demand in the region and current political instability can lead to serious disruptions in energy supply. Therefore, another objective of this article is to briefly assess how energy policies are being planned and organized in each of Mercosur+2 countries (including Venezuela and Bolivia), providing a more holistic interpretation of energy security.

The justifications for this research are as follows: (i) there are few studies that work with the concept of energy security in the face of a regional logic [1]; (ii) little research focusing on regional cooperation and integration as ways of ensuring energy security has been conducted so far [2]; (iii) the existing studies focus on Organization for Economic Co-operation and Development (OECD) or Southeast Asian countries; (iv) there are few critical comparative studies in the area [3]; and (v) there are no studies working with comparative energy policies within Mercosur to date.

This paper presents two approaches. First, through a literature review, we aim to fill the existing gaps by demonstrating how the accepted definitions of energy security are outdated, obsolete and do not consider many current issues—such as environmental, political and regional issues. Second, we suggest a specific socio-environmental-energy security (SEES) index. We propose a new index that can be used for multifold purposes, such as to create energy scenarios and projections, to define public and private policies, and to guide comparative analysis due to its feasibility [4].

This index is fully committed to the assessment and measurement of energy security, which should not be only understood as a mismatch between supply and demand of energy; rather, it must also consider social and environmental factors. To ensure sustainability in the region, it is essential to consider social, economic and environmental aspects equally.

Indicators facilitate orientation in a complex world, condensing large amounts of information into a recognizable pattern. According to the literature, about 75% of recent studies employ no more than 20 indicators into their analysis, which will certainly help us in creating a simpler and more useful particular intersectoral index.

The analysis will be based on data from 1990 onwards. Data and statistics on primary energy will be provided by the International Energy Agency (IEA), while macroeconomic statistics have been taken from the World Bank database and national public data. Commodity trade data come from the United Nations Commodity Trade Statistical Database (UN Comtrade). Other specific statistics were obtained from the Ministry of Energy and Environment of the respective countries.

2. Reevaluating the Energy Security Concept

This section presents the debate on the concept of energy security. In the first subsection, we discuss the common-sense perspective. Then, the following subsection suggests an alternative proposal that considers social, environmental and regional spheres.

2.1. Common-Sense Perspective

The concept of energy security comes from the 20th century, more precisely from the 1970s oil crises when the central concern was reducing dependence on oil imports, particularly in OECD countries [3,5,6]. The academic debate ended up weakened by the stabilization of the oil price (1990s), but stable prices played a key role in the countries' strategic agenda, particularly because of: (i) increasing demand in Asia; (ii) interruption of gas supply in Europe; and (iii) pressure to decarbonizing energy systems [7–10].

Indeed, the literature on energy security is strongly influenced by both price oscillation and guaranteeing of demand from primary sources, such as oil and gas [4,8,11–17]. However, energy security is not limited to this matter. It is a dynamic definition that encompasses dimensions that evolve as circumstances change over time. Therefore, it is imperative to refer to this concept considering its dynamic components in order to provide a comprehensive analysis of energy within Mercosur. In this sense, Chester (2010) sums up the multiple aspects of the term "energy security", noting that an inherent characteristic of the concept is risk management (interruption, unavailable power supply, capacity failure, dependence on sources of unsustainable energy, etc.).

There are 4 main elements when we talk of energy security: (i) availability of energy; (ii) accessibility; (iii) costs; and (iv) environmental sustainability [18]. There are also 4 variables that need to be incorporated into the concept: (i) environment; (ii) technology; (iii) demand-side management; and (iv) sociocultural factors [19]. After all, we have a concept that refers to "securing the amount of energy required for people's life, economic, and social activities, defense and other purposes for acceptable prices" [20].

In this way, what is perceived is that there are several interpretations and understandings about the concept of energy security, which has undergone changes since the 1970s. In almost 50 years, even the International Energy Agency (IEA) itself had to incorporate these changes into their own definitions. In 1985, IEA defined energy security as "an adequate supply of energy at a reasonable cost" [21] (p. 29); in 2007, however, it states that "energy security always consists of both a physical component and a price component, (but) the relative importance of these depends on market structure" [22] (p. 32). But it is only in 2010 that its definition includes "while respecting environmental concerns" [7].

Currently, the agency's website contains the following definition: "the IEA defines energy security as the uninterrupted availability of energy sources at an affordable price. Energy security has many aspects: long-term energy security mainly deals with timely investments to supply energy in line with economic developments and environmental needs. On the other hand, short-term energy security focuses on the ability of the energy system to react promptly to sudden changes in the supply-demand balance". It is then clear that environmental and investment issues rest exclusively on long-term analysis, while the short-term ones focus on the mismatch between supply and demand.

Regarding the definition of energy security, there is a significant tendency to use indicators to measure it. This methodology compares and measures the evolution of energy security in several countries [3,19,23], having some authors that suggest a differentiation between ex-ante and ex-post indicators [24].

The concept of energy security has evolved over time, addressing new issues such as efficiency, international relations, environmental protection and institutional dimensions [25,26]. It goes beyond OECD oil importing countries as a proxy for this concept, even illustrating the role of non-state actors, from individual economies to global production networks [7,27].

There is research that provides an exhaustive analysis of 104 studies on energy security (including peer-reviewed journals, national agency reports, international organizations and business/professional associations) since 2001 [4]. It also assesses if these studies have a particular definition of energy security, if there is any indicator/composite index to evaluate the concept, as well as if it takes infrastructure, prices, social effects, environment, governance and efficiency taking into account.

The authors note that the average number of studies per year increased during this period and that the percentage of qualitative and quantitative studies is very similar. In this way, a qualitative and a quantitative analysis will be done in this paper, so that they can complement each other and provide a more complete overview.

Before proceeding with our analysis for Mercosur we would like to emphasize that there are almost no papers dealing with energy policies in Latin American countries, nor in those countries within Mercosur. There are only 6 papers that include at least one country part of this bloc [28–33]. This is another reason why this paper focuses on this regional bloc.

2.2. A More Particular Perspective

Given the evolution of energy security, as well as the complexity of existing definitions and methodologies used to deal with this concept, we highlight the need to understand 3 significant differences when it comes to this matter:

- **Classical studies vs. Contemporary studies**: in the 1970s and 1980s, energy security basically meant stable supply of cheap oil under threat of embargoes and price manipulations by exporters [7,34]. In this sense, the concept was very close to national values such as political-economic independence, territorial integrity and oil autonomy/sovereignty. On the

other hand, contemporary studies on energy security incorporate a number of other factors, such as mitigation of climate change, equitable provision of energy services, and socio-political stability [10,35];

- **Developed countries vs. Developing countries**: it is necessary to take into account the socio-economic status of the countries to analyze the concept of energy security [2,4]. For more developed countries, the concept represents a resilient energy system with uninterrupted availability of energy sources at an affordable price [36]; notwithstanding, to less developed countries it can mean access to modern energy services [37]. Thus, we extend the concept to developing countries, stating that it refers to "sufficient energy supply (quantity and quality) to meet all requirements at all times of all citizens in affordable and stable price, and it also leads to sustain economic performance and poverty alleviation, better quality of life without harming the environment" [38] (p. 653);
- **Short-term analysis vs. Long-term analysis**: generally, in the short and medium-term analysis, energy security focuses on the impacts of price shocks or unanticipated supply disruptions; but in the medium-term, the promotion of renewable energy to deal with oil dependence can be considered [39]. In the long-term, we consider the profile of demand, infrastructure, depletion of reserves, technological innovation, climate change, adaptability of systems, among other variables [2,40]. We also suggest that the analysis should be separated into short and long-term [41]. Nevertheless, it is essential to understand that energy policies that may lead to increased energy security in the short-term may not guarantee it in the long-term [4].

After these clarifications, we propose an alternative approach which intends to deal more adequately with numerous contemporary issues. This proposal considers the reality of developing countries such as the ones part of the Southern Common Market (Mercosur), suggesting the socio-environmental-energy security (SEES) approach. Therefore, in the following subsections we will explain the reasons why these two dimensions (social and environmental) are included and then why the analysis will take place at the regional level.

2.2.1. Social

When analyzing developing countries, it is essential to take into account regional and national inequalities and asymmetries. Critics of energy indicators have already drawn attention to social inequalities when using energy indicators for certain regions [25]. In this way, a central issue in contemporary studies of energy security is to identify and explore the relationships between energy systems and social values [7].

In terms of development and sustainability, developed countries focus almost exclusively on environmental issues, while in developing countries issues such as poverty and equity are of primary priority [42]. Consequently, the inclusion of social indicators, such as those related to energy poverty, is essential for the Mercosur case study.

Therefore, it is clear that energy indicators are not limited exclusively to energy issues per se. Among the challenges that need to be incorporated into the new concept of energy security, we should consider human security [3], stressing that the new conceptualization of energy security must take into account the provision of basic energy services, that is, access to electricity.

2.2.2. Environmental

Some authors suggest that we need to take into account environmental impacts in order to understand energy security, mainly when it comes to developed countries or in the medium/long-term analysis. However, what is 'environmentally acceptable' varies considerably among different actors, such as local people, environmental non-governmental organizations (NGOs), industries, and nation states [7].

Energy security can be understood as "the ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the economy" [43] (p. 6). Some authors also consider the environmental and climate change impacts on energy systems in their studies [2,8,18,25,36,39,44].

However, when considering environmental variables, it is necessary to take into account the risk of a possible dilemma. By promoting renewable alternatives to conventional energy sources, we can add risks and threats to the energy system, such as intermittency and high operating costs. As these alternative energies still do not scale in certain markets, costs remain high for many regional contexts.

The presence of social and environmental effects on energy security definitions has grown significantly, particularly post 2010—even though they are only about 40% of the cases analyzed [4]. In this research, the authors show that the environmental dimension is often addressed in recent papers, securing a second place and only falling behind the economic dimension, whereas the social sphere is in the fifth position.

2.2.3. Regional

Indeed, Yergin's classic definition of energy security brings us to the idea of an exclusively national concern. This influence, present in the mainstream literature of Economics and International Relations, shaped energy security to become a priority issue of every country's national agenda. Consequently, state-centered definitions of energy security prevail.

A challenge that must be incorporated into the new concept of energy security (contemporary definition) is the consideration of the international scale, since it can include regional and global events [3]. In fact, countries have been increasingly engaging in foreign policy and energy diplomacy to ensure energy security from the relationship with exporting countries [4,45–47].

However, as well as the renewable energy dilemma, cross-border pipelines and strategic transformation channels, among other factors of increased complexity, can deepen the risks and uncertainties of supply disruption due to political issues, wars, technical failures, accidents, geographic and geological catastrophes, extreme weather events and turbulence in financial markets [8,10,16,39,48]. Precisely because of these side effects, regional energy integration should be more than a simple arrangement of integrated energy markets and systems, but a political project with full participation of the parties involved in order to jointly mitigate such risks and threats.

Notwithstanding, there is a risk of political instability when one thinks of regional energy security, as occurred with the interruption of gas supply in GASBOL (between Brazil and Bolivia) and more recently in Europe (Russian gas) [1,8]. It is worth mentioning that this type of behavior, hindering or refusing to sell energy to importing countries, is often referred to as an "energy weapon" [24].

Taking into account that the three dimensions presented are relevant in the context of Mercosur, the next section will make a case analysis of the region. The characteristics of the countries, as well as their energy policies, will be analyzed.

3. Case Study

In order to avoid insisting on a worn out debate of almost half a century, we propose the concept of socio-environmental-energy security (SEES) to deal with the reality of Southern Common Market (Mercosur) countries. Mercosur was created in 1991 under the Treaty of Asunción, promoted by then Brazilian President Fernando Collor de Mello and Argentine President Carlos Menem, whose main objective was to create a common market between Argentina, Brazil, Paraguay and Uruguay.

In the present work, we will evaluate Mercosur+2 (or Mercosur 6), also considering Venezuela (effective adhesion in mid-2012) and Bolivia (accession process in progress since 2015) as new effective members. Although nowadays Venezuela's situation is confusing—due to the non-definitive suspension in December 2016, the country will be considered in the time series analysis.

Table 1. Socioeconomic indicators for Mercosur+2 countries.

Countries	Area (km^2)	Population (Millions Hab.) [3]	Urban Population (%) [3]	Life Expectancy (Years) [2]	Birth Rate (Annual Average Rate/1000 Hab.) [2]	Mortality (Annual Average Rate/1000 Hab.) [2]	HDI [3]	Gini Index [4]	GDP at Current Prices (US$ bi) [3]
Argentina	2,766,889	41.4	91.5	76.0	16.9	7.7	0.8	42.7	610
Bolivia	1,098,581	10.7	67.7	66.9	25.9	7.2	0.7	48.4	31
Brazil	8,511,965	200.0	85.2	73.6	15.1	6.4	0.7	51.5	2246
Paraguay	406,752	6.8	59.2	72.2	23.9	5.7	0.7	51.7	29
Uruguay	176,215	3.4	95.0	76.9	-	9.3	0.8	41.6	56
Venezuela	916,445	30.4	88.9	74.5	20.1	5.3	0.8	44.8	227
Mercosur+2	13.876.847	292.7	81.3	73.4	20.4	6.9	0.7	46.8	3199

Source: Own elaboration based on ALADI Statistics and World DataBank; GDP = gross domestic product; HDI = human development index; FOB = free on board (price of merchandise made available at the place of manufacture or storage); CIF = cost, insurance and freight (price includes merchandise cost and insurance and freight costs [2] = data for 2012, [3] = data for 2013, [4] = data for 2014 (except Venezuela, with data for 2011).

It should be noted that in the specific case of Mercosur, most literature mainly deals with the trade agenda. Among the most cited and relevant works, commercial transactions and policies stand out as proxies for the integration of the bloc. Most pieces of research discuss the Mercosur region exclusively in light of trade and tariff issues, disregarding other relevant topics within this regional bloc. This is the main reason why there is a lack of literature on the energy sector in Mercosur, also neglecting the study of energy policies within this initiative. Therefore, this is another reason for investigating the energy situation of this regional bloc.

Table 1 shows that there are many differences between the countries within Mercosur+2, in terms of surface, population and socioeconomic development. Due to these asymmetries, it is necessary to take into account the social aspect as one of the three dimensions in order to measure socio-environmental-energy security (SEES) in the region, because mitigating such asymmetries is one of the main goals of any regional integration process [49].

Considering the differences and peculiarities of each of the Mercosur countries, the following section will give a brief analysis of their recent energy policies. The period of analysis of each country varies to consider the latest national plans that have an important impact on the design of energy policies.

3.1. Energy Policies

In this section, we make a brief comparative analysis of several qualitative variables in order to summarize recent energy policies in the different Mercosur+2 countries. Thus, we sought to shed light on the inexistence of an effective regional policy for the bloc countries, since the existing policies are heterogeneous and uncoordinated. Nevertheless, this diversified pattern can actually encourage and promote greater regional energy integration.

Table 2 shows how the concept of energy security changes between different countries in the same region [2]. However, although Table 1 shows the presence of differences in socioeconomic development of Mercosur+2 countries, it is worth noting that there are already interconnections in the energy markets of the region, what may make it easier to promote possible regional cooperation and/or energy integration projects.

With regard to Argentina, it is clear that the country lacks investments linked to the production of renewable energy, although, like Uruguay, the country has programs with goals and targets established to promote the diversification of energy matrices. The analyses are based on the most recent and most credible program in the Argentinean scenario, the RenovAR Plan de Energías Renovables [50], which aims to intensify, through Law 27.191/2015, the production of renewable energy for territorial development and new technologies, the latter in order to support public services.

In any case, the country has a rich energy potential and this fact explains the possibility of Argentina being found among the world's largest producers of renewable energy, with biofuel as its flagship. In this way, it would leave the list of importing countries and would appear as a producer-exporting country, also guaranteeing an economic relief to Argentine coffers. However, it should be pointed out that Argentina's energy policy is criticized by domestic sectors for not being placed as a state policy, as shown by the recent Decree of 2017, characterized by President Mauricio Macri as 'the year of renewable energies'.

Uruguay has been investing in the renewable energies, but unlike other countries in the bloc (such as Argentina), it does not aim to enter the world market. The Uruguayan goal is actually to guarantee domestic energy supply without running climate risks and intensify the technological-social development within its own borders. The National Energy Policy 2005–2030 report [51] is one of the main bases of the current Uruguayan energy policy.

Both Bolivia and Venezuela take into account the classic aspects of energy security; which are the guarantee of generation, and internal and external supply. Both national energy policies can be recognized as "resource nationalism" [52], given that the state is the main actor in managing energy resources. Besides, both countries actively promote energy integration within Mercosur countries,

but not only bilaterally, as in the case of the Bolivia-Brazil gas pipeline (GASBOL), but also off the bloc, as in the case of Venezuela and the countries of Latin America and Caribbean (LAC).

Although Venezuelan regional energy integration initiatives touch on the use and development of renewable energies and show concern for the environment, there are no initiatives contemplating using renewables in the domestic sector. Strongly based on the Siembra Petrolera Plan 2005–2030 [53], Venezuelan energy policy has among its principles the classic vision of energy security, which is to meet domestic demand and generate resources through export to fund various infrastructure initiatives, not only in energy, but in all Venezuelan productive sectors and services.

Particularly in Bolivia, there is great potential to exploit alternative energy resources. In areas where the state cannot meet and supply the demand for energy, renewable energy is being considered an alternative. The major challenge that Bolivia faces today is to apply its energy potential to large urban centers and to large-scale generation, serving not only the population, but also the production and service sectors. More recently, the country has participated in debates towards constructing bi-national hydroelectric plants with Brazil in the Amazon region, aiming to become a net regional exporter. Among the main directives regulating Bolivias's energy policy, it is possible to cite the Expansion Plan of the National Interconnected System 2012–2022 [54], the Plan for Universal Energy Access 2010–2025 [55] and the Bolivian Alternative Energy Policy [56].

Table 2. Energy policies variables in Mercosur+2.

Variables	Argentina	Bolivia	Brazil	Paraguay	Uruguay	Venezuela
Role of the STATE	Passive actor	Nationalism of resources	Protectionist (a)	Nationalism of resources	Main actor (regulator)	Nationalism of resources
Private Initiative	Active	Until 2005	Yes	No	Regulated Participation	No
Public-Private Partnerships (PPP)	Yes	Until 2005	Yes. Opening of capital in 1995	No	Yes (under the mediation of the Executive Power)	No
Focus on Demand Guarantee	Yes	Yes	Yes	Yes (PND 2030)	Yes	Yes (b)
Divides Analysis into Short and Long-Term?	Yes	Yes	Yes (c)	Yes	Yes	Yes
Mention Environmental Issues	Yes	Yes	Yes, always in documents	Yes (d)	Yes	Yes
Mention Regional Integration	Yes	Yes	No	Yes (e)	Yes (with the countries of the bloc)	Yes (f)
Encourages Renewable/Alternative Energies	Yes	Yes (g)	Yes (h)	Yes (i)	Yes	Yes (j)
Focuses on Non-renewable Resources	Yes (l)	Yes (l)	Yes (pre-salt reserve)	No	No	Yes (l)

Source: Own elaboration. (a) aiming at preserving the national interest, according to Law N. 9,478/1997; (b) despite facing a serious internal crisis; (c) through short plans and document PNE2030; (d) due to its essentially hydroelectric matrix; (e) with a view to selling the Itaipu surplus to other countries; (f) with LAC countries; (g) biomass; (h) plans for hydroelectric, wind and solar; (i) only the maintenance of the hydroelectric plant; (j) despite mentioning the issue in regional and international organizations, internal practice is not observed; (l) maintenance of the fossil matrix.

Both Brazil and Paraguay have great energy potential, considered as a geopolitical resource. In each of these countries, energy security is treated in a particular and differentiated way, and its formulation is based on structured energy policies in the short and long-term. It is worth highlighting the joint initiative (regional energy integration) among the countries, named Itaipu Binacional, which represents a great success case in terms of South-American energy integration.

Brazil is the largest Mercosur country in territorial dimensions, but it is not the largest energy producer in the region, it ranks in second place due to Venezuela's high production of non-renewable energy. However, in terms of renewable energy, focusing on hydroelectric and wind production, Brazil

is the largest producer, and the third largest producer of hydroelectric power, in the world. For the country, Proalcool plays a crucial role since the 1970s and Law 13.033/2014 regulates the mandatory addition of biodiesel to diesel oil sold to the final consumer.

The National Energy Efficiency Plan [57] is the most important document for Brazil, published by the Ministry of Mines and Energy (MME) in 2011. In this report, Brazil's energy composition is assessed, emphasizing its energy self-sufficiency in several sectors, such as in heavy oil, and the country's 2030 National Energy Plan [58], which is being implemented since 2007. It is important to note that other similar plans have already been existing for at least two decades, such as the Electric Energy Conservation Program (PROCEL) and the National Program for Rational Use of Oil Products and Natural Gas (CONPET).

Paraguay is the fourth largest producer of energy in Mercosur, with its predominantly renewable energy sources coming from the bi-national hydroelectric plants Acaray (1970), Itaipu (1984) and Yacyretá (1994). Thanks to hydropower production, the country ranks 7th in the ranking of the world's largest clean energy producers, becoming a net exporter. In 2014, the government published the National Development Plan 2030 [59], which analyzes the country's economic, development, environmental and social scenario, in order to establish development goals. Although there is no specific topic for energy development, the document states that Paraguay is currently a country based on clean energy development policies, focusing on social development and production of thinkers, so that it can improve its productive sector.

Identifying the asymmetries that exist between the Mercosur countries, which imply different energy policies, is fundamental to understanding that the concept of energy security is not capable of dealing with or incorporating such particularities. Thus, the following section proposes a new concept, suggesting the adoption of different indicators to consider new issues that are now incorporated into the energy concern, particularly when it comes to developing countries.

3.2. Socio-Environmental-Energy Security (SEES) Index

After analyzing the energy policies in Mercosur+2 countries and perceiving their differences, it is important to evaluate how they are translated into energy security. To this end, it is proposed to create a hybrid approach based on the socio-environmental-energy security (SEES) index in order to assess the evolution in this region as well as within countries. In fact, there has been a tendency in energy security studies to quantify energy security using indicators and indexes [4], either to compare performances across countries (space studies) or to evaluate them over time (time studies). Our objective here is to do both analyses simultaneously, without doing a forecast analysis (scenario projection studies), but evaluating the performance of the Mercosur+2 SEES during 23 years (1990–2013).

To guarantee sustainability, we must provide equal weight to economic, social, and environmental aspects [42]. Consequently, the weight given to social, energy and environmental indicators will be exactly the same due to the equal importance they have: (i) promotion of universal access to energy services (especially due to national and regional asymmetries); (ii) the guarantee of demand (increasing demand, particularly as they are developing countries); and (iii) the environmentally sustainable management of natural resources (renewable and non-renewable).

The data used are publicly accessible from international databases, such as World DataBank, OECD Statistics, ECLAC Data and IEA Statistics. After defining the indicators, data selection, normalization, weight assignment and aggregation, the SEES composite index is generated.

The evaluation was conducted based on 15 indicators gathered from the review of previous studies. The total of indicators is in line with the methodology performed in most studies, since about 75% of them employ less than 20 indicators in the analysis [4]. These indicators, as anticipated, were divided into three dimensions: social (S), energy (E) and environmental (A). Each one of them is based on the literature on energy security, energy policy, environmental studies and international relations. For each indicator, data ranging from 1990 to 2013 was collected for each of the 6 Mercosur+2 countries.

Due to the recent enlargements of the bloc, with the effective accession of Venezuela in mid-2012 and Bolivia, whose ratification process has been taking place since 2015, the former was considered in the analysis only in 2013; because of the lack of public data from 2015, Bolivia was not considered in the data analysis. In addition, although Mercosur was formed in 1991, we use data from 1990, since some indicators were only available for decades. As is clear from Table 3, the energy dimension incorporates indicators relating to (geo)political (E1 and E2) and technological (E4) matters.

Table 3. Socio-environmental-energy security (SEES) Indicators.

Dimension	Code	Indicator	Unit	Source
Social (S)	S1	Access to electricity, rural	% of rural population	WB
	S2	Access to electricity, urban	% of urban population	WB
	S3	Electricity consumption per capita	kWh per capita	IEA
	S4	Total final consumption (TFC) per capita	toe per capita	IEA
	S5	Total primary energy supply intensity	toe per thousand 2005 USD	CEPAL
Energy (E)	E1	Fuel exports	% of merchandise exports)	WB
	E2	Net oil imports/GDP	toe per thousand 2005 USD	WB
	E3	Total natural resources rents	% of GDP	WB
	E4	Electric power transmission and distribution losses	% of output	WB
	E5	Investment in energy with private participation	current USD	WB
Environmental (A)	A1	CO_2 emission per capita	t CO_2/capita	IEA
	A2	CO_2 intensity	kg CO_2/2005 USD	IEA
	A3	Energy related methane emissions	% of total	WB
	A4	Nitrous oxide emissions in energy sector	thousand metric tons of CO_2 equivalent	WB
	A5	Renewable energy consumption	% of total final energy consumption	WB

Source: Own elaboration based on data from ECLAC Statistics, IEA Statistics and World DataBank. It should be noted that selected indicators did not show available data for 2013 (S1, S2, E3, E5, A3, A4 and A5).

Since the indicators usually have different units and scales, it is necessary to make a transformation before aggregating them in order to generate the composite index [4]. The min-max normalization, the most popular method used in different relevant and famous studies [25,29,60–68], was performed to allow a linear transformation of the original data. Thus, a new scale, ranging from 1 to 10, is guaranteed by the process described below:

$$X' = 1 + \left(\frac{X - Min_A}{Max_A - Min_A} \right) x(10 - 1) \quad (1)$$

where: X' = normalized value based on 1–10 scale; X = value map; Min_A = minimum value of the data range A (1); Max_A = maximum value of the data range A (10).

It is worth mentioning that there are indicators that are inversely proportional to the scale, that is, larger values correspond to a lower value for the socio-environmental-energy security, therefore the maximum value has to be considered as minimum, reversing function 1 (S4, S5, E2, E3, E4, A1, A2, A3 e A4). Regardless of the case, the SEES should not be understood based on the value per se, but on the relative change of ordinal values over time.

4. Results and Discussion

In this section, we will briefly analyze the results of the SEES analysis in Mercosur. Note that, unlike previous analysis considering Bolivia and Venezuela, the previous data analysis does not include them because data and indicators for both countries were not available from 2010 on. In addition, as already reported for 1990, certain data are not available. Therefore, to avoid analytical bias after standardization, it is necessary to present a graphical analysis only for the period from 1990 to 2010, at five-year intervals.

Figure 1 highlights the evolution of SEES in Mercosur for the entire period under analysis. The aggregate index varied little for the years presented, indicating a slight downward trend.

The understanding of this phenomenon comes from the detailed and disaggregated analysis of the dimensions, since, particularly from 2005 to 2010, the environmental dimension fell from 6.5 to 4.2, respectively. This was particularly affected by the lack of data for indicators A3 and A4 for the year 2010.

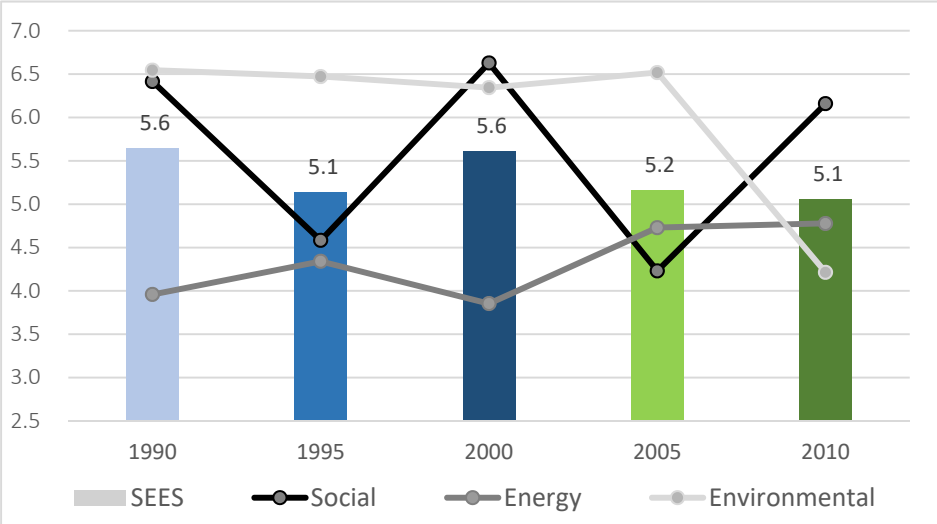

Figure 1. Evolution of SEES in Mercosur (1990–2010).

The social dimension fluctuated significantly in the period, with significant declines in 1995 and 2005. This, again, was due to the lack of data in those years for indicators S1 and S2. However, it is worth noting that the trend for the social dimension is falling from 1990 to 2010, from 6.4 to 6.2—although it grows from 1990 to 2000. Even though the decrease is small, it is due to the reduction of S2 in Brazil (data from 2000 seem overestimated, as in the case of Paraguay), S4 in Paraguay (which may not necessarily be bad), and S5 in Argentina, Paraguay and Uruguay (increase the intensity of the primary energy supply per unit of GDP).

It is important to stress that the decrease of final total final consumption per capita (S4) is not a problem itself for these countries. In fact, S4 is not included in the selection of indicators that count negatively for SEES, since, because they are developing countries, the increase in per capita consumption seems to be positive for this country profile. However, there may have been a change in the final aggregate consumption pattern (more rational and/or efficient) leading to these results.

The energy dimension, in turn, sustains a growth trend throughout the period analyzed. Indicators E2 and E3 are mainly inverse dynamics, since if net oil exports (E2) are positive, it means that countries are exporting more and it reflects in the income associated with the exploitation of resources (E3), or that countries are importing less. In addition, E4 falls to Brazil and Paraguay in the period analyzed due to transmission losses and losses in distribution, whether they are technical losses (inherent to the transmission of electricity in the network) or non-technical (energy theft, measurement errors, etc.). In both countries, there have been a number of policies aimed at reducing transmission and distribution losses, regardless of the reasons. It should also be noted that there is no data for E5 in the case of Paraguay (1990–2010) and Uruguay (2005 and 2010).

Moreover, we must address some limitations associated with the quantitative analysis of the data that need to be taken into account. The first one is the sensitivity of the index to the lack of indicator data, what is actually expected from a normalization method. Second, the selection of indicators does not take into account electricity tariffs (US$/kWh), which could be considered in the social dimension, basically because there was no available data to allow comparison during the whole time series. Thirdly, it should be noted that weighing countries and indicators in the SEES index may also have an implicit bias, but in order to avoid overestimating or underestimating certain countries' results,

we maintained the same relative weight of each of them in the index calculation. In addition, a more detailed analysis of the transformation of the energy matrices for this period would allow a better understanding of the results presented by each one of the 15 indicators. These limitations will be incorporated in future work, mainly due to the current lack of available data.

5. Conclusions

Energy models are no more reliable in predicting a single future indicator than social or environmental models; this is why the three dimensions should be taken into account together. In this scenario, considering the quantitative indicator-based approach to the index proposed, less complex frameworks with small sets of some key indicators have proved to be more appropriate to analyze energy policies.

Regarding the Mercosur region, it should be noted that energy integration can contribute to the better performance of (regional) energy planning—given the asymmetry of national policies. This energy integration must be marked not only by commercial energy flows, but rather by institutional, regulatory and political harmonization. Mercosur countries should then seek the coordination and complementation of regional energy policies, as well as the possibility of harmonizing regional regulatory frameworks.

After establishing and evaluating indicators to provide a socio-environmental-energy security (SEES) index, it is expected that it will guide policy recommendations based on an indicator-based approach to the context of the region. Having done so, we can ensure a more holistic, intersectoral and appropriate approach to the subject.

Altogether, it is fundamental: (i) to doubt and speculate about the concept of energy security, (still) the basis of the world's energy planning; (ii) to distinguish that the analysis at regional level can not be explained in light of national ones; (iii) to incorporate social and environmental concerns into energy analysis; (iv) to replace the old and far-reaching concept of energy security with the SEES one, particularly for developing regions; and (v) to develop regional integration, as it may represent a key driver in the SEES guarantee.

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