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Furthering regional energy security instead of national approaches

Fomentando la seguridad energética regional en lugar de los enfoques nacionales

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ABSTRACT

This paper argues that furthering energy security should move beyond a national approach and consequently consider a regional one. The case study considers Mercosur and UNASUR, covering the period between 2015-2050. The methodology is based on energy modeling and scenarization using the Open Source Energy Modelling System – South America Model Base (OSeMOSYS-SAMBA), a model of planning for the expansion of long-term energy systems. The modeling exercise supports the argument that greater electricity integration in Mercosur (and in South America as a whole) promotes a reduction in the need to increase installed capacity, as well as lower geographic and socio-environmental impacts.

Keyword: Energy Security; Energy Integration; Mercosur; UNASUR.

JEL Codes: C6, N76, O13, Q4.

RESUMEN

El artículo argumenta que la promoción de la seguridad energética debe ir más allá del enfoque nacional y, en consecuencia, considerar uno regional. El estudio de caso considera el Mercosur y la UNASUR, cubriendo el período 2015-2050. La metodología se basa en el modelado y la creación de escenarios de energía utilizando el Open Source Energy Modelling System – South America Model Base (OSeMOSYS-SAMBA), un modelo de planificación para la expansión de los sistemas de energía a largo plazo. El ejercicio de modelado ratifica el argumento de que una mayor integración eléctrica en el Mercosur (y en América del Sur en general) promueve la reducción en la necesidad de aumentar la capacidad instalada, así como menores impactos geográficos y socio ambientales.

Palabras clave: Seguridad Energética; Integración Energética; Mercosur; UNASUR.

Clasificación JEL: C6, N76, O13, Q4.

1. INTRODUCCIÓN

Traditionally, the discussion of energy issues in International Relations and Economics has been focused on oil, based on geopolitics or energy security viewpoint, from the state-centric bias. This state-centric bias, strongly present in national energy plans, consequently makes it difficult or even impossible to understand and suggest policies at the regional level.

In this sense, the present paper aims to present qualitatively and quantitatively the gains associated with the promotion of regional energy integration/security. First, we discuss the concepts of regional integration and energy integration and present the main benefits and obstacles to it. Then, there is a quantitative analysis based on the scenarization and quantitative modeling. To this end, the case of the Southern Common Market (Mercosur), a regional initiative dating back to the 1990s, will be considered.

Thus, the present work seeks not only to present a theoretical-conceptual discussion about regional energy integration, but also to present a case study based on quantitative modeling to show the real gains related to greater Mercosur energy integration. Gains from the point of view of installed capacity (impact on territorial geography), electricity generation and electricity exchanges (impact on optimization of the system) and emissions of greenhouse gases (impact on emissions) will be evaluated.

2. SHADING LIGHT ON ENERGY INTEGRATION

There is no precise definition of *energy integration* in the current literature, suggesting that it should be interpreted as a process that involves at least two countries and that aims at promoting regional energy industry through a permanent installation and based on a specific agreement that guides the relationship rules between the parties (Oxilia, 2009). However, it can be argued that 'energy integration and, more widely, infrastructure integration, represents the cornerstone of a new level of regional integration', that is perfectly in line to the central argument of this paper (Lima and Coutinho, 2006: 363).

States deal with this sector by taking into account ordinary notions such as *energy planning*, *diversification of energy matrix*, and *energy self-sufficiency* (Santos, 2014). We note that such concepts are equally important when linked to energy security. Particularly, the concept of self-sufficiency ends up being a great barrier to the promotion of regional energy integration.

In the case of countries in South America, particularly the Mercosur countries, the possibility of exploring synergies derived from hydrological complementarity, as well as different sources, has been highlighted (Moura, 2017; Ramos, 2016). Thus, there is evidence of a strong complementarity between the different pluviometric regimes in the region, which suggests the joint planning of the dispatch of hydroelectric dams, construction of new ventures and joint management of decision-making.

Again, in the context of South America and particularly the Southern Cone, there is a diversity of financial sources coming from regional and international financial institutions that have, among their portfolio of projects, those involved in the issue of energy integration (Padula, 2013; Santos, 2014), such as the Inter-American Development Bank (IADB), the World Bank (WB), the Brazilian Development Bank (BNDES), the Development Bank of Latin America (CAF) and the Financial Fund for the Development of the Río de Plata Basin (FONPLATA).

The literature often stresses the importance of Brazil in the region's energy integration process. This should be due to (i) being the largest energy market in the region, with a consistent economic model for expanding production capacity; (ii) having borders with 10 of the 12 countries in South America; and (iii) its previous expertise in national energy integration, with the creation of the National Interconnected System (SIN) (Santos, 2018).

In this sense, the obstacles to regional energy integration begin to appear. In addition to the issue of Brazilian hegemony in the region, there is a significant lack of convergence and consensus on political, macroeconomic and microeconomic issues, which makes any regional integration initiative a major challenge (Santos, 2014). This reality ends up being reflected in the asymmetry of development and technical and technological power between Brazil and its neighbors, especially the smaller ones (Biato *et al.*, 2016).

An obstacle to this broader integration process is the Brazilian commercial model applied since 2004, since it relies on the sale of electricity certificates (physical guarantee), defining a closed, planned and operated model in an optimized and centralized way. It is not trivial to incorporate into this model the energy imported from other countries, unless there is contractual and legal security to consider it in the long-term Brazilian energy planning.

In general, there are institutional and regulatory asymmetries that make the implementation of energy integration projects in the region too complex and costly (Queiroz *et al.*, 2013). This complexity and diversity should be reduced in order to minimize economic uncertainties, legal insecurities and political risks.

Since the regulatory framework of South American countries was based on different experiences in time and space, the current model presented by each country is quite different, especially regarding the environment, opening up to private (and foreign) capital and strategic planning of the sector (Santos, 2014). Consequently, institutional conditions in the region still have a major influence over the technical, commercial and contractual relations in the integration process (Queiroz and Vilela, 2010).

In order to avoid political risks and 'loss of sovereignty' in the majority of extra-national energy projects, countries seek to promote enterprises of binational nature. However, the logic of these actions has almost always been subordinated to the interests of national energy planning and not to an integrated and systemic policy for the whole region; in other words, each country individually designs its annual energy plan, its investment prospects, and its short/medium term interests (Santos, 2014).

As 'side effects', energy integration can lead to reduced energy self-sufficiency (energy interdependence) and the operational autonomy of systems, which is one of the main resistance to its implementation. Moreover, given the need for harmonization of regulatory frameworks, the complexity of defining legal frameworks, treaties, norms and rules, as well as possible shocks in diplomatic relations between countries, should be highlighted. It is also possible to stress the increase in risks related to changes in the previously agreed conditions, through interventions by governments, such as through the definition of new legislation and taxation (subsidies and administered prices) and the expropriation of assets.

From the existence of different benefits and barriers to energy integration in Mercosur, we established that it would be necessary to deal with issues of commercial, operational and institutional natures. Events such as nationalization of assets (Bolivia and Venezuela), interruption of contracted energy supply (Argentina to Chile, and Venezuela to Roraima, and Petrocaribe) and request for renegotiation of the agreement signed (Paraguay from Brazil, in the case of Itaipu) created a bad and pessimistic history for the advancement of the process.

3. SCENARIZATION AND QUANTITATIVE MODELING

After briefly analyzing benefits and barriers to energy integration, this section aims to model and analyze possible scenarios of energy integration in the region, using the case of the power sector to illustrate its potential. The power sector was considered as a case study of energy modeling, given the social relevance of ensuring access to electricity at affordable prices, particularly when it comes to developing countries.

The scenarios were modeled in the OSeMOSYS-SAMBA. This model provides long-term cost-optimization of the power expansion planning of South America countries, being an open source, dynamic, bottom-up and multi-year power sector framework that allows us to deal with large-scale linear programming problems.

Data on existing regional infrastructure was used and the expansion plans of the countries. The base-year is 2013, with four scenarios built for the period 2013–2050. Features related to population growth, electricity demand, costs, hydro reservoirs, technological performance, reserve margin time zones and carbon emissions were considered. 2013 is a strategic base-year for the model because from that date we have to consider that the United Nations General Assembly unanimously declared the decade 20142024 as the Decade of Sustainable Energy for All (SE4ALL). This stresses the relevance of energy issues for sustainable development and for the elaboration of the post-2015 development agenda.

The following features are key assumptions of the model: (i) technological changes are provided by exogenous learning curves based on IEA ETP reports; (ii) time resolution is 12 months, divided into 4 intra-day periods and time horizon is 2013-2058, yearly steps; (iii) reserve margin is 15% (only dispatchable technologies are able to meet it); (iv) real discount rate is 8% and monetary values is 2013 US$; (v) there are also three time zones: 1st: Argentina, Brazil (NE, S and SE) and Uruguay; 2nd: Bolivia, Brazil (N), Chile, Paraguay and Venezuela; and 3rd: Colombia, Ecuador and Peru; (vi) carbon electricity intensity to be reduced by 34% by 2058 (IEA, 2014); (vii) subsidies for national fuel prices are eliminated in the long-term, allowing convergence to international prices; (viii) regarding losses in T&D systems, both reduction costs and increasing efficiency of generating technologies are considered; and (ix) existing oil refining capacity and international pipelines limit countries' national supply.

The availability of natural gas for electricity generation was restricted for SAMBA scenarios, so, producing and importing countries cannot use more than 50% of the extracted/imported resource in the power sector. In addition, Argentina and Brazil are the only countries expected to develop shale gas production (due to their large reserves and land availability) and new nuclear plants.

A 34% reduction, by 2058, in the overall electricity's carbon intensity was imposed when structuring the SAMBA scenarios, following results achieved by IEA WEO (2014) for non-developed countries. For Argentina, Bolivia, Brazil, Chile and Peru a maximum installed capacity investment of large-scale electricity production using Concentrated Solar Power (CSP) plants per year is up to 1 GW, while it is 100 MW for Colombia and Venezuela. The same assumptions were applied to investments in large-scale solar photovoltaic plants.

Based on the current energy infrastructure of the region, on some projects suggested by the CIER 15 Project (because many were not implemented), on the national expansion plans of the countries, and on official data and in academic analyzes, four scenarios were proposed: reference integration scenario (RIS), weak integration scenario (WIS), moderate integration scenario (MIS) and strong integration scenario (SIS). It is important to make clear that all scenarios are prepared by the author and are created based on official energy expansion plans of the countries analyzed.

3.1. Assumptions

Similarly to selected projects by CIER Project 15, changes in alternative scenarios can be classified as: (i) type I interconnection (operational security and opportunity exchanges); (ii) type II interconnection (operational security and energy export); (iii) use of infrastructure ('swaps'); (iv) hydroelectric with export contracts (economies of scale); and (v) binational plants. Regarding the nature of the alternative policies for each of the alternative scenarios, they can be divided into the following goals: (i) diversification of the power generation mix; (ii) consideration of socio-environmental vulnerability; (iii) increasing in international transactions; and (iv) harmonization of regulatory frameworks.

Table 1 below presents general information for each of the scenarios modeled in OSeMOSYS-SAMBA.

Table 1. OSeMOSYS-SAMBA integration scenarios general data

Scenario	Focus	Measures
RIS	National	BAU
WIS	National	Reduction of HPP expansion + reduced cost of second generation biogas + distributed PV (Br)

Scenario	Focus	Measures
MIS	Southern Cone	Ar-Br: Garabí (1,152 MW) + Panambí (1,048 MW)
		Ar-Py: Aña Cuá (2.000 MW) + 1st and 2nd Yacyretá expansion (1,550 MW) + Itacorá-Itatí (1,660 MW) + Corpus (3,500 MW)
		Bo: El Bala 1 e 2 (3,676 MW) + Rositas (400 MW)
		Bo-Ar: TL Yaguacua - Pichanal - San Juancito (1,200 MW)
		Bo-Pe: 2 TLs (1,150 MW)
		Bo-Cl: TL (180 MW)
SIS	South America	Bo-Br: Cachuela Esperanza (990 MW)
		Ar-Py-Br: TL (2,000 MW)
		Py-Ar-Cl: 'Swap' of energy (200 MW)
		Co-Ec-Pe-Cl-Bo: SINEA (3,120 MW)

Source: Santos (2018), ENDE (2017), IMF (2016), Yépez et al. (2016), COES-SINAC (2016), CIER (2017), Bertero (2015), National Expansion Plans, IIRSA, BN Americas, BID, FOCEM-Mercosur, ENDE, ENDE Andina, Hydro Review, Consulado de Bolivia, Siemens and BN Americas. Cl = Chile; Co = Colombia; Ec = Ecuador; HPP = hydro powe plant; Pe = Perú; PV = photovoltaics; TL = transmission line.

Reference integrate scenario (RIS) corresponds to business as usual (BAU) scenario, being the baseline scenario. It considers national expansion plans projected by Mercosur governments (short, medium and long-term), in addition to 23 existing international interconnections. As it can be seen, in the reference integration scenario (RIS), there are several policies and energy investments in (and among) Mercosur countries, with particular emphasis on Bolivia. This country does not currently have energy interconnections with its neighbors, despite being in the center of the South American subcontinent.

Table 2. Reference integration scenario (RIS) detailed data

Country	Project	Investment (US$ millions)	Technology	Installed capacity	Year
Ar	Vaca Muerta (Neuquén)	40	Shale gas	55 MMm3/day; 135 MMm3/day; 270 MMm3/day	2020; 2025; 2030
	Electricity Losses in T&D	-	T&D losses	15%	2013
Bo	Miguillas 1 – Palillada (La Paz)	448	Hydro	118 MW	2019
	Miguillas 2 – Umapalca (La Paz)		Hydro	85 MW	2022
	Misicuni (Cochabamba)	142	Hydro	120 MW	2018
	Ivirizu (Cochabamba)	550	Hydro	280 MW	2022
	San José 1 (Cochabamba)	245	Hydro	55 MW	2018
	San José 2 (Cochabamba)		Hydro	69 MW	2019
	Solar Uyuni (Potosí)	94	Solar PV	60 MW	2018
	Solar Yunchará (Tarija)	9.4	Solar PV	5 MW	2018
	CC Entre Ríos (Cochabamba)	463	Thermal	380 MW (currently owns 100 MW)	2020
	CC de Warnes (Santa Cruz de la Sierra)	406	Thermal	320 MW (currently owns 160 MW)	2020
	CC Del Sur (Tarija)	463	Thermal	320 MW (currently owns 160 MW)	2020
	Incahuasi Field (Santa Cruz)	1.2	Natural gas	7 Mm3/d (currently owns 4.7 Mm3/d)	2017
	Electricity Losses in T&D	-	T&D losses	14%	2013
Br	Electricity Losses in T&D	-	T&D losses	15%	2013
Py	TL Itaipu - Villa Hayes	555	TL	1,200 MW	2014
	Rios interiores	1.14	Hydro	500 MW	2025
	Electricity Losses in T&D	-	T&D losses	27%	2013
Uy	Electricity Losses in T&D	-	T&D losses	19%	2013
Ve	Electricity Losses in T&D	-	T&D losses	33%	2013
Ar-Br	'Swap' entre Brasil-Argentina	-	TL	2,000 MW	2017
Br-Uy	Pte. Médici (Br) - San Carlos (Uy)	349	TL	500 MW	2017

Source: Own elaboration based on MS (2017), IMF (2016), YÉPEZ et al. (2016), BERTERO (2015), BID, FOCEM-Mercosur, ENDE, ENDE Andina, Hydro Review, Consulado de Bolivia, Siemens, BN Americas.

Weak integration scenario (WIS) is based on the reference integration scenario (RIS). As with RIS, its focus is also national, precisely because it does not include advances of new regional integration projects. As its name suggests, there will be no progress of any project under study. In addition to what is considered in RIS, it considered lower hydro expansion capacity and reduced investment costs of biogas (from second generation) power plants and addition of distributed photovoltaic (PV) in Brazil. Considering the already presented nature of alternative policies, it is perceived that WIS presents diversification of the power generation mix and considers socio-environmental vulnerability, without having any projects that increase international transactions and/or contribute to the harmonization of regulatory frameworks.

The maximum capacity expansion in hydro plants in Brazil was set at a lower level of up to 200 MW per year in the Northern subsystem, 100 MW in the subsystems of the South and Southeast and no hydro expansion in Brazil's Northeast. In addition, distributed PV was considered only in the electricity supply mix of Brazil to assess the impact of the penetration of this technology in 10% of total households, due to recent new regulations. Regarding the third measure, it was assumed that the long-term investment cost of new biogas power plants (US$ 2.449/kW) will converge with the investment cost of bagasse incineration plants in 2013 (US$ 1.905/kW) in Brazil (Moura, 2017).

Moderate integration scenario (MIS), as well as the weak integration scenario (WIS), is based on the reference integration scenario (RIS). The focus is on the moderate expansion of Mercosur region energy integration projects, considering national hydro projects in Bolivia and international interconnections between the countries analyzed. Considering the already presented nature of the alternative policies, we note that the moderate scenario presents diversification of power generation mix, socio-environmental vulnerability, and has (bi)national projects that increase international transactions, without any connection to the desired harmonization of regional regulatory frameworks.

Table 3. Moderate integration scenario (MIS) detailed data

Country	Project	Investment (US$ millions)	Technology	Installed capacity	Year
Bo	El Bala 1 Component 1 (Angosto Chepete 400)	6.912	Hydro	3,251 MW	2030
	El Bala 2 Component 2 (Angosto El Bala 220)		Hydro	425 MW	2043
	Rositas	1	Hydro	400 MW	2024
Bo	TL with Ar, Br, Pe and Py	622	TL	8,000 MW (Br) + 700 MW (Ar)	2020*
Bo-Ar	Yaguacua (Bo) - Tartagal (Ar) - San Juancito (Ar)	60	TL	1,200 MW	2019
Bo-Cl	Punutuma (Bo) - Radomiro Pomic (Cl)	30.5	TL	180 MW	2021
Bo-Pe	Azángaro (Pe) - Juliaca - Puno (Bo)	81.3	TL	1,000 MW	2021
	La Paz (Bo) - Puno (Pe)	65	TL	150 MW	2022
Py	TL Yacyretá - Villa Hayes	297	TL	300 MW	2019
Ar-Br	Garabí (quota 89)	2.728	Hydro	1,152 MW	2026
	Panambí (quota 130)	2.474	Hydro	1,048 MW	2026
Ar-Py	Yacyretá - Aña Cuá	610	Hydro	270 MW	2022
	Yacyretá – 1st expansion (Yacyretá 3)	100	Hydro	465 MW	2023
	Yacyretá – 2nd expansion (Yacyretá 7)	2.3	Hydro	1,085 MW	2027
	Yacyretá - Itacorá-Itatí	6	Hydro	1,660 MW	2029
	Corpus Christi (Pindoí)	9	Hydro	3,500 MW	2030

Source: Own elaboration based on ENDE (2017), IPPSE (2017), SOL.bo (2017) and KOUTOUDJIAN (2015); * 100 MW every year from 2020.

As its name suggests, **strong integration scenario (SIS)** is the most audacious scenario. To be viable, there must be a series of changes such as: (i) political will; (ii) diplomatic engineering; (iii) institutional development; (iv) adaptation/harmonization of regulation related to cross-border trade; and (v) advancement of transmission and interconnection infrastructure. Precisely because of this, it was modeled on the moderate integration scenario (MIS), which already considers some of these prerequisites. Regarding this scenario, more than focusing on the expansion of installed capacity, we seek to optimize the use of existing infrastructure in the region. It is not limited to Mercosur countries (and their neighbors, to the extent that there are joint projects), but the analysis is extended to all of South America. Therefore, countries such as Ecuador and Colombia are considered, comprising almost all the States Parties and Associated States of Mercosur, making up almost the whole of South America.

Considering the already presented nature of the alternative policies, we can see that the SIS presents a diversification of the power generation mix, considers socio-environmental vulnerability, has (bi) national projects that increase international transactions and presupposes the desired harmonization of regional regulatory frameworks. In this sense, this is the only scenario that acknowledges all the different natures of the alternative policies considered in the model. In this scenario, there are only projects involving two or more countries. Only one extra dam is considered, although it is facing popular resistance to development (Cachuela Esperanza), given its socio-environmental impacts. At the same time, swaps are considered between Paraguay, Argentina and Chile. Finally, the scenario considers new international interconnections, with Chile, Ecuador and Peru.

Table 4. Strong integration scenario (SIS) detailed data

Country	Project	Investment (US$ millions)	Technology	Installed capacity	Year
Bo-Br	Cachuela Esperanza (Beni)	2.46	Hydro	990 MW	2030
Ar-Py-Br	(500 kV, 321 km)	-	TL	2,000 MW	2030
Py-Ar-Cl	Swap de energía Paraguay - Argentina - Chile	-	TL	200 MW	2025
Co-Ec*	Alférez (Co) - Jamondino (Co) - Inga (Ec)	-	TL	800 MW	2020
Cl-Bo*	Chuquicamata (Cl) - Laguna Colorada (Bo)	30	TL	120 MW	2020
Pe-Ec*	La Niña (Pe) - Daule (Ec)	522.25	TL	1,000 MW	2022
Pe-Cl*	Los Héroes (Pe) - Arica (Cl)	131.5	TL	200 MW	2020
	HVDC Montalvo (Pe) - Crucero (Cl)	989	TL	1,000 MW	2024

Source: Own elaboration based on CIER (2017), LARREA et al. (2017), COES-SINAC (2016), OLADE (2013), DAR (2011), IIRSA, BN Americas; * SINEA Project.

3.2. Results

The following tables and figures will provide a comparative analysis of total installed capacity (GW) and total (TWh) and technology generation, as well as electricity exchanges between countries (TWh), share of international transmission lines in total generation (%), and total emissions (MtCO2e). **Table 5** summarizes a comparative analysis between installed (GW) and generation (TWh) capacities of the four scenarios discussed.

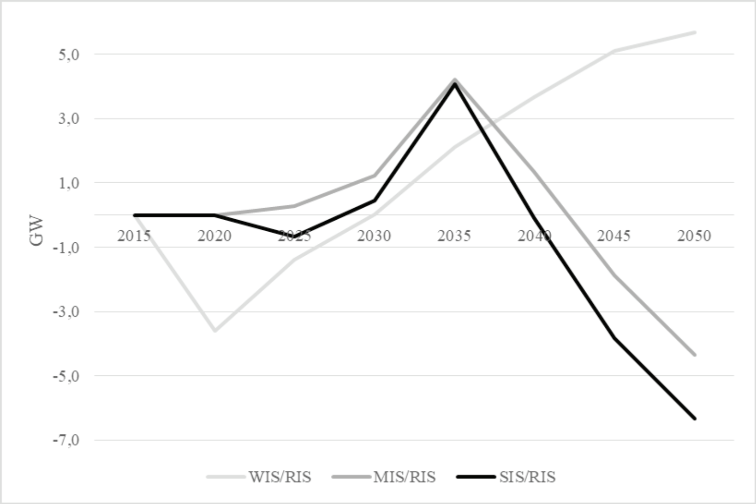
Table 5. Comparative installed capacity and generation, by scenario (2015-2050)

Scenarios	Installed capacity (GW)					Generation (TWh)				
	2015	2025	2035	2045	2050	2015	2025	2035	2045	2050
RIS	209.1	244.2	307.5	405.4	460.0	911.7	1,094.4	1,347.0	1,691.9	1,894.3
WIS	209.1	242.9	309.7	410.5	465.7	911.7	1,131.8	1,385.2	1,727.9	1,933.7
MIS	209.1	244.5	311.8	403.6	455.7	911.7	1,095.4	1,349.9	1,693.2	1,896.2
SIS	209.1	243.6	311.6	401.6	453.7	911.7	1,094.6	1,348.5	1,690.9	1,894.9

Source: Own elaboration.

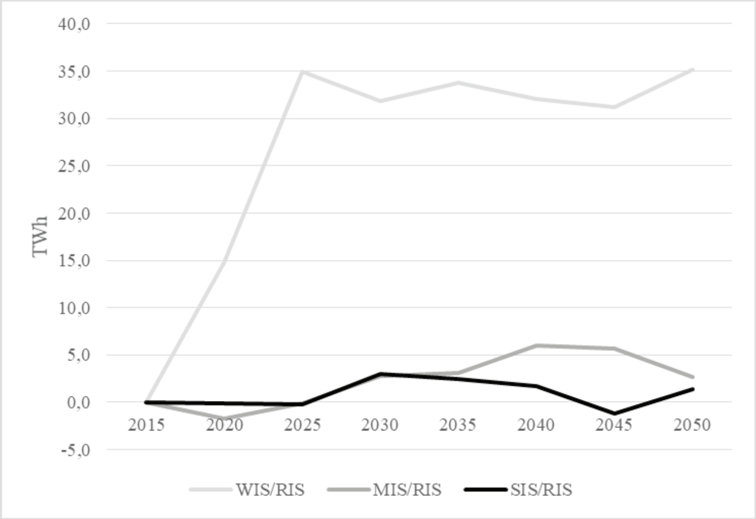
Figure 1 shows the graphical evolution of installed capacity (GW) for each alternative scenarios (WIS, MIS and SIS) relative to RIS; thus, each curve indicates the difference of the values of the scenarios analyzed against RIS. It is clear the direct relationship between greater integration and reduction of the need to increase regional installed capacity. Against the trend of MIS and SIS, there is an increasing trend in WIS installed capacity.

Figure 2 does the same analysis of Figure 1, but based on the evolution of Mercosur generation (TWh). Again, the previous argument is ratified as it considerably increases the generation in WIS.



Source: Own elaboration.

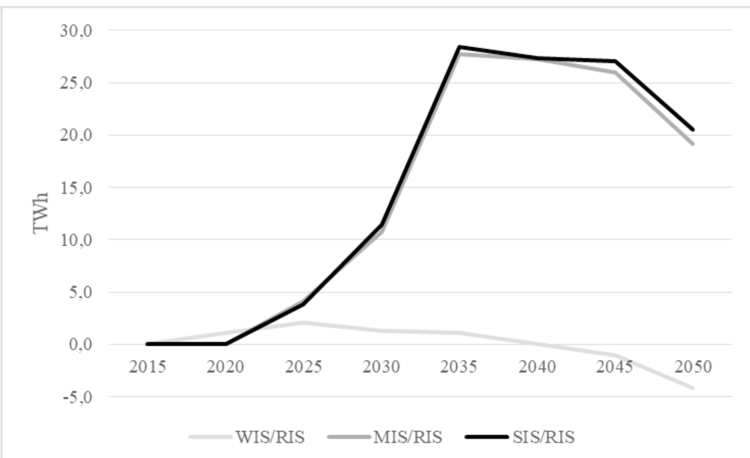
Figure 1. Comparative evolution of net installed capacity related to RIS, by scenario, in GW (2015-2050)



Source: Own elaboration.

Figure 2. Comparative evolution of net generation related to RIS, by scenario, in TWh (2015-2050)

Figure 3 shows the evolution of electricity exchanges (TWh) for the period 2015-2050 compared to the RIS. Again, the fall in WIS relative to MIS and SIS stands out. There is both the evolution of the electricity exchanges (TWh) and the evolution of its capacity factor (%) for South American countries. Despite having installed capacity expansion in most countries in the region, transmission through international interconnections in MIS and SIS is increasing, especially in 2035 and 2045. On the other hand, in the case of WIS, this figure falls sharply from 43.2TWh (2015) to 17.2 TWh (2050). In spite of an increase in transactions in TWh, the capacity factor of LTs falls in all scenarios.



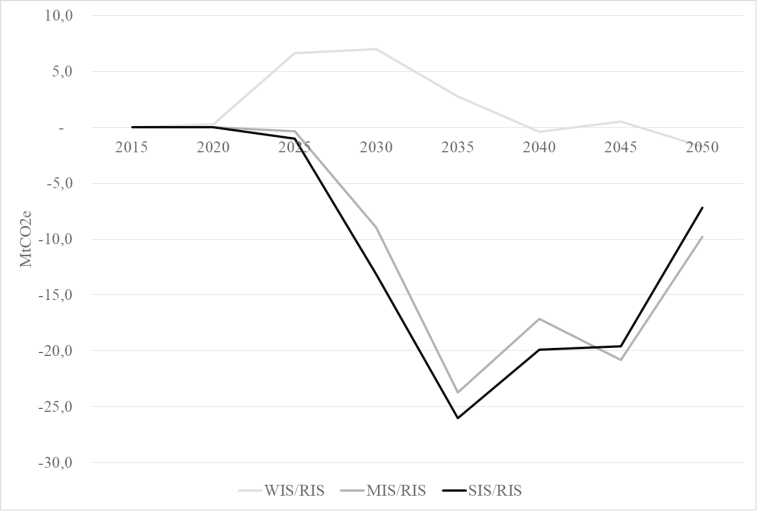
Source: Own elaboration.

Figure 3. Comparative evolution of net electricity exchanges related to RIS, by scenario (2015-2050)

With regard to emissions, Figure 4 shows that there is a significant fall in MIS and SIS compared to RIS. This is due to the substitution of new thermal power generation for more intensive use of current installed capacity (expansion and new hydroelectric plants, increase of capacity factor of international interconnections, and advancement of renewables sources). Thus, energy integration in Mercosur (and

South America as a whole) can (and should) consider the diversification of power generation mix and the limitation of generation from non-renewable energies in order to unlock new sustainable growth opportunities and to improve the resilience of energy systems.

Therefore, it is possible to notice that the change of installed capacity and generation with the initiatives in the different scenarios is quantitative and mainly qualitative (due to substitution by renewable energies). In terms of installed capacity, the change in RIS in 2050 is +5.7 GW (WIS), -4.4 GW (MIS) and -6.3 GW (SIS). Regarding generation, the change in RIS in 2050 is +32.1 GW (WIS), +1.9 GW (MIS) and +0.6 GW (SIS) is lower, since there are no extra assumptions about the demand behavior between the scenarios; in fact, maintaining demand on smaller installed capacity impacts capacity factor of existing plants and TLs.



Source: Own elaboration.

Figure 4. Comparative evolution of net emissions related to RIS, by scenario, in MtCO2e (2015-2050)

4. CONCLUSIONS AND RECOMMENDATIONS

From the existence of different benefits and barriers to energy integration in Mercosur, we established that it would be necessary to deal with issues of commercial, operational and institutional natures. Events such as nationalization of assets (Bolivia and Venezuela), interruption of contracted energy supply (Argentina to Chile, and Venezuela to Roraima, and Petrocaribe) and request for renegotiation of the agreement signed (Paraguay and Brazil, in the case of Itaipu) created a bad and pessimistic history for the advancement of the process.

With regards to commercial nature, it is necessary to facilitate international energy exchange and to consider risk management, especially in long-term contracts. With regard to the operational nature, it is necessary to consider regional planning and the technical peculiarities of each market. Regarding the institutional nature, it is essential to promote regulatory harmonization and to develop regional energy alliances and treaties. We then conclude that all these issues, in a progressive way, will guarantee the legal certainty, credibility and transparency necessary for the execution of the projects, whose profile is generally capital intensive and long term.

The modeling exercise supported the argument that greater electricity integration in Mercosur (and in South America as a whole) leads to a reduction in the need to increase installed capacity, as well as to lower geographic and socio-environmental impacts. Notwithstanding, it will undoubtedly require *political will* and 'diplomatic engineering' to carry out the measures of each scenario in the face of such adverse political-economic context.

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