REGIONAL ENERGY SECURITY: RE-EVALUATING CONCEPTS AND POLICIES TO PROMOTE ENERGY INTEGRATION IN MERCOSUR

Thauan dos Santos

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'Nuestro norte es el sur'

Joaquín Torres García

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SEGURANÇA ENERGÉTICA REGIONAL: REAVALIANDO CONCEITOS E POLÍTICAS PARA PROMOVER A INTEGRAÇÃO ENERGÉTICA NO MERCOSUL

Thauan dos Santos

Fevereiro/2018

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Programa: Planejamento Energético

Esta tese realiza uma revisão de conceitos e políticas relacionadas à segurança energética e à integração regional. Dessa forma, propõe-se que o planejamento energético nos países em desenvolvimento seja regional, incorporando as dimensões social e ambiental da energia. Com foco nos países do Mercosul, considerando inclusive Venezuela (2012) e Bolívia (2015), faz-se uma análise comparada geral em termos quantitativos e qualitativos dos mercados e da infraestrutura física dos países do bloco (e da América do Sul, como um todo). Em seguida, analisa-se o papel que as instituições regionais, como o Mercosul e a UNASUL, desempenha na área de energia, mostrando que sua contribuição para a integração energética da região é muito pequena. A seguir, é proposto um índice híbrido (SEES index) para avaliar a evolução das políticas energéticas do Mercosul no período 1990-2010. Posteriormente, usa-se o modelo OSeMOSYS-SAMBA para simular quatro cenários de integração regional do setor elétrico, escolhido como exemplo dada a sua relevância. Por fim, conclui-se que a integração energética do Mercosul deve ser promovida, uma vez que reduz a necessidade de ampliação da capacidade de geração de energia elétrica e os impactos socioambientais dos projetos na área de energia.

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This thesis presents an overview of concepts and policies related to energy security and regional integration. Follows a proposal that energy planning in developing countries becomes regional, incorporating both social and environmental dimensions of energy. Focusing on Mercosur countries, including Venezuela (2012) and Bolivia (2015), a general comparative analysis is carried out, not only in quantitative and qualitative terms of the markets, but also of the physical infrastructure of the member countries (and of South America, as a whole). Then, comes an analysis of the role that regional institutions, such as Mercosur and UNASUR, have played in energy integration, showing that their contribution is very small. Next, a hybrid index (SEES index) is proposed to assess the evolution of Mercosur's energy policies in the period 1990-2010. Follows the application of OSeMOSYS-SAMBA model to simulate four scenarios for the integration of the power sector, used to illustrate the case due to its relevance. Finally, we conclude that Mercosur's energy integration should be promoted, since it reduces both the need to invest in the extansions of power supply and the socio-environmental impacts associated to electricity projects in the region.

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LIST OF ACRONYMS

ABAR	(Brazilian) Association of Regulatory Agencies
ABRADEE	(Brazilian) Association of Electric Energy Distributors
ACL	(Brazilian) Free Contracting Environment
ACR	(Brazilian) Regulated Contracting Environment
ADME	(Uruguayan) Electric Market Administration
AFCSE	(Bolivian) Electricity Control Authority
AFD	French Development Agency
AHBG	(Mercosur) Ad Hoc Group on Biofuels
ALADI	Latin American Integration Association
ALBA	Bolivarian Alternative for the Peoples of Our America
ANA	(Brazilian) National Water Agency
ANCAP	(Uruguayan) National Administration of Fuels, Alcohols and Portland Cement
ANDE	(Paraguayan) National Electricity Administration
Aneel	(Brazilian) National Electric Energy Agency
ANH	(Bolivian) National Hydrocarbons Agency
ANP	(Brazilian) National Agency of Petroleum, Natural Gas and Biofuels
APEC	Asia-Pacific Economic Cooperation
API	(IIRSA-COSIPLAN) Integration Priority Project Agenda
Ar	Argentina
ARPEL	Latin America and the Caribbean
ATC	Available Transfer Capacity
ATS	Alternative Trade SAMBA
BANDES	Venezuela Economic and Social Development Bank

BAU	Business As Usual
BB	Bank of Brazil
BCB	Central Bank of Bolivia
BES	Brazilian Electricity Sector
BG	British Gas
BNDES	Brazilian Development Bank
Bo	Bolivia
Br	Brazil
BRACIER	Brazilian Committee of CIER
CAF	Andean Development Corporation/Development Banck of Latin America
CAMMESA	(Argentine) Wholesale Electricity Market Administrator Company
CAN	Andean Community
CANDU	Canadian Deuterium Uranium
CASA	South American Community of Nations
CBDR	Common But Differentiated Responsibilities
CEPEL	(Brazilian) Electrical Energy Research Center
CES	(UNASUR) South American Energy Council
CCEAR	(Brazilian) Energy Trading Contract in Regulated Environment
CCEE	(Brazilian) Electric Energy Trading Chamber
CCI	(Brazilian) Facilities Sharing Agreements
CCS	Carbon Capture and Storage
CCT	(Brazilian) Transmission System Connection Agreements
CFEE	(Argentine) Federal Electrical Energy Council
CGEE	(Brazilian) Energy Efficiency Management Committee
CIER	Regional Energy Integration Commission
c.i.f	Cost Insurance and Freight
Cl	Chile

CMC	(Mercosur) Common Market Council
CMG	(Mercosur) Common Market Group
CMSE	(Brazilian) Power Sector Monitoring Committee
CNDC	Bolivian National Load Dispatch Committee
CNEP	(Paraguayan) National Council of Public Companies
CNPE	(Brazilian) National Council of Energy Policy
Co	Colombia
CO_2	Carbon dioxide
CO_{2eq}	Carbon dioxide equivalent
COBEE	Bolivian Power Company
COCIER	Colombian Committee of CIER
CONAM	(Paraguayan) National Council of the Environment
CONAMA	(Brazilian) National Environment Council
CONPET	(Brazilian) National Program for the Rational Use of Oil Products and Natural Gas
COP	Conference of the Parties
Corpoelec	National Electricity Corporation S. A.
COSIPLAN	South American Council of Infrastructure and Planning
CPST	(Brazilian) Transmission Services Agreement
CSN	South American Community of Nations
CSP	Concentrated Solar Power
CUST	(Brazilian) Contract of Use of the Transmission Systems
CWE-MC	CWE Market Coupling
DEC	Decision
DIT	(Brazilian) Other Transmission Facilities
DNE	(Uruguayan) National Energy Directorate
EBIH	Bolivian Hydrocarbons Industrialization Company

EBISA	*Emprendimientos Energéticos Binacionales S.A.*
EBS	*N. V. Energiebedrijven Suriname*
EBY	Yacyretá Binational Entity
Ec	Ecuador
ECLAC	(United Nations) Economic Commission for Latin America and the Caribbean
ECSC	European Coal and Steel Community
EDELAP	(Argentine) Distribution Company of La Plata S.A.
EDENOR	(Argentine) *Distribution* and Marketing Company of the *North* S.A
EDESUR	(Argentine) South Distribution Company S.A.
EDF	*Electricité de France S.A*
EE	Energy Efficiency
E&P	Exploration and Production
EID	(IIRSA) Integration and Development Hubs
Eletrobras	Brazilian Electric Power Company S.A.
EMCC	European Market Coupling Company
EMDE	Emerging Markets and Developing Economies
ENAGAS	(Venezuelan) National Gas Entity
ENARGAS	(Argentine) National Regulatory Entity for Gas
ENDE	(Bolivian) National Electricity Company
ENRE	(Argentine) National Electricity Regulatory Entity
EPE	(Brazilian) Energy Research Company
ESBR	Sustainable Consortium of Brazil
ETP	Energy Technologies Perspectives
EU	European Union
EURATOM	European Atomic Energy Comunity
Exp	Exports

f.o.b	Free On Board
FOCEM	Mercosur Structural Convergence Fund
FONPLATA	Financial Fund for the Development of the Río de Plata Basin
FTZ	Free-Trade Zone
GASBOL	Bolivia-Brazil Gas Pipeline
GDP	Gross Domestic Product
GEA	Guyana Energy Agency
GHG	Greenhouse Gas
GMC	(Mercosur) Common Market Group
GOPLAN	Technical Group of Planning Agencies
Gt	Guatemala
GTB	*Gas TransBoliviano S.A.*
GTOR	Working Group of Electricity Regulatory Organizations
GVC	Global Value Chains
Gy	Guyana
HDI	Human Development Index
HPP	Hydro Power Plants
HW&L	Heat, Waste & Losses
HVDC	high-voltage, direct current
IBGE	Brazilian Institute of Geography and Statistics
I(A)DB	Inter-American Development Bank
IEA	International Energy Agency
IET	International Electricity Transactions
IIRSA	Initiative for the Integration of Regional Infrastructure in South America
IMF	International Monetary Fund
Imp	Imports
IOC	International Oil Companies

IRENA	International Renewable Energy Agency
IS	Isolated Systems
LAC	Latin America and the Caribbean
LAIA	Latin American Integration Association
LOSSEL	(Venezuelan) Organic Law on the Public Service of Electricity
LPG	Liquefied Petroleum Gas
MCTIC	(Brazilian) Ministry of Science, Technology, Innovation and Communications
MDG	Millenium Development Goals
ME	(Bolivian) Ministry of Energy
MEM	(Argentine) Wholesale Electricity Market
MER	(Central American) Regional Electricity Market
Mercosur	Common Market of the South
MH	(Bolivian) Ministry of Hydrocarbons
MHE	(former Bolivian) Ministry of Hydrocarbons and Energy
MIBEL	Iberian Market
MIEM	(Uruguayan) Ministry of Industry, Energy and Mining
MIC	(Paraguayan) Ministry of Industry and Commerce
MINEM	(Argentine/Peruvean) Ministry of Energy and Mining
MIS	Moderate Integration Scenario
MMA	(Brazilian) Ministry of Environment
MME	(Brazilian) Ministry of Mines and Energy
MOPC	(Paraguayan) Ministry of Public Works and Communications
MOU	Memorandum Of Understanding
MPetroMin	(Venezuelan) Ministry of the Popular Power of Petroleum and Mining
MPPEE	(Venezuelan) Ministry of Popular Power for Electric Energy
MUEVE	(Uruguyan) Electric Mobility Exhibition

Mx	Mexico
N	North
NAMA	Nationally Appropriate Mitigation Actions
NCRE	Non-*Conventional Renewable* Energies
NE	Northeast
NEP	New Environmental Paradigm
NGCC	Natural Gas Combined Cycle
NGOC	Natural Gas Open Cycle
NGL	Natural Gas Liquid
NGPP	Natural Gas Processing Plants
NIS	(Brazilian/Paraguayan/Bolivian) National Interconnected System
NPS	Nord Pool Spot
OECD	Organisation for Economic Co-operation and Development
O&G	Oil and Gas
OLADE	Latin American Energy Organization
ONS	(Brazilian) National System Operator
OPEC	Organization of the Petroleum Exporting Countries
OSeMOSYS	The Open Source energy Modelling System
Pa	Panama
PA	Paris Agreement
PAC 2	(Brazilian) Growth Acceleration Program 2
PAE	(IIRSA) Strategic Action Plan
PDSEN	(Venezuelan) Development Plan for the National Electric System
PDVSA	*Petróleos de Venezuela*, S.A.
Pe	Peru
Petrobras	*Petróleo Brasileiro S.A.*
Petropar	*Petróleos Paraguayos S.A.*

PMR	Partnership for Market Readiness
PPI	Private Participation in Infrastructure
PPP	Public-Private Partnership
PPSA	(Brazilian) *Pre-Sal Petróleo S.A.*
PROCEL	(Brazilian) National Electricity Conservation Program
PROINFA	(Brazilian) Alternative Energy Sources Incentive Program
PSI	(IIRSA) Sectoral Integration Processes
PV	Photovoltaic Power Plant
PX	Power Exchange
Py	Paraguay
PWR	Pressurizer Water Reactor
RE	Renewable Energy
REC	Recommendation
REIDI	(Brazilian) Special Regime for Incentives for Infrastructure Development
RES	Resolution
Rio+20	United Nations Conference on Sustainable Development
RIS	Reference Integration Scenario
RNEST	Abreu e Lima Refinery
RenovAr	(Argentine) Renewable Energy Program
RFB	Federal Revenue of Brazil
RMMA	(Mercosur) Meeting of the Environment Ministers
RMME	(Mercosur) Meeting of Ministers of Mines and Energy
S	South
SA	South America
SADI	Argentine Interconnection System
SAMBA	South America Model Base
SAVE	(Uruguayan) Electric Vehicle Power Systems Network

SDG	Sustainable Development Goal
SE4ALL	Sustainable Energy for All
SEAM	(Paraguayan) Secretariat of the Environment
SE/CO	Southeast/Midwest
SEES	Socio-Enviromental-Energy Security
SGT	Working Subgroup of Mercosur
SHP	Small Hydroelectric Power Plant
sieLAC	Latin America and the Caribbean Energy Information System
SIEPAC	Central American Electrical Interconnection System
SINEA	Andean Electrical Interconnection System
SING	(Chilean) Interconnected System of the Norte Grande
SMEs	Small and Medium Enterprises
SPG	(Brazilian) Oil, Natural Gas and Biofuels Secretariat
SSE	(Brazilian) Electric Energy Secretariat
ST	(Argentine) Trunk System
STAT	(Argentine) High Voltage Electric Power Transport System
SIS	Strong Integration Scenario
Su	Suriname
TBG	*Transportadora Brasileira Gasoduto Bolívia-Brasil S.A.*
T&D	Transmission and Distribution
TGN	(Bolivian) National Treasury
TGU	Turbogenerator Units
TIE	International Energy Transactions
TL	Transmission Line
TLC	Trilateral Market Coupling
TPP	Thermal Power Plant
TUST	(Brazilian) Tariffs for Use of Transmission System

U_3O_8	Uranium
UN	United Nations
UNASUR	Union of South American Nations
UNDSN	United Nations Sustainable Development Solutions Network
UNFCCC	United Nations Framework Convention on Climate Change
UPME	(Colombian) Mining and Energy Planning Unit
UREE	(Venezuelan) Rational Use of Electric Power
URSEA	(Uruguayan) Regulatory Unit of Services of Energy and Water
USA	United States of America
UTE	(Uruguayan) National Administration of Power Plants and Electric Transmissions
Uy	Uruguay
VAT	Value-added tax
Ve	Venezuela
VMATE	(Bolivian) Vice-Ministry of High Energy Technologies
VMME	(Paraguayan) Vice Ministry of Mines and Energy
VMEEA	(Bolivian) Vice Ministry of Electricity and Alternative Energies
VNG	Vehicular Natural Gas
YPBF	*Yacimientos Petrolíferos Fiscales Bolivianos S.A.*
YPF	(Argentine) Fiscal Oilfields S.A.
WB	World Bank
WEC	World Energy Council
WEO	World Energy Outlook
WIS	Weak Integration Scenario

LIST OF UNITS

bbl	barrel
bcm	billions cubic meters
boe	barrel of oil equivalent
BTU	British Thermal Unit
cal	calorie
g	gram
G	giga = 10^9
J	Joule
k	kilo = 10^3
kbbl/d	1000 barrels per day
kWh	kilowatt-hour
m	meter
M	mega = 10^6
MMCFD	million cubic feet day
MWe	megawatt elétrico
MWp	megawatt peak
pp	percentage point
t	ton
tCO_2	tons of carbón dioxide
TCF	trillion cubic feet
toe	tons of oil equivalent
US$	American dollars
W	watts

1. Introduction

The introduction will be divided into three sections. The first one (section 1.1) presents a general overview of the main themes and discussions of the thesis. The second one (section 1.2) highlights the objectives of the research, as well as its originality. Finally, the third one (section 1.3) presents the thesis structure and contents.

1.1 General overview

Energy has been playing an essential role in the history of societies throughout the most different ages. From the discovery of fire, to industrial revolutions, access, domination and use of energy, it has always been strategic for human survival and well-being, as well as for economic growth and development itself. In fact, as the binomial domain-dependence of energy became more evident, the more obvious was the need for humans to develop technologies and mechanisms to have their control.

It became important to have energy *domain*, mainly having access to different resources 'in the backyard', that is, domestically; however, when this was not possible, different contractual/commercial arrangements, wars and/or interventions took place in order to dominate it. By dominating energy and basing an entire model of production and patterns of consumption on certain energy sources, *dependence* started increasing and seemed to have no return. In this sense, the binomial domain-dependency of energy began to control and even determine technological, economic, political, social and undoubtedly environmental relations within and between *countries*.

Thus, energy has become and continues to be a priority theme in the *national* strategic agenda. In effect, the terms 'countries' and 'national' were intentionally detached, since energy has increasingly become a sensitive issue linked to state sovereignty, as it is vital for its development. Therefore, it was essential to have guaranteed access to energy somehow.

Since energy ccan be understood as a strategic priority sector, it needs specific planning and policies. This is particularly true especially because energy not only provides the production of basic goods/services, but also guarantees the well-being of the population.

This rationale is confirmed by the fact that many experts and policy makers already consider energy as a public good (KARLSSON-VINKHUYEN *et al*., 2012, BARRETT, 2007).

Therefore, energy planning becomes paramount to guarantee energy security. However, two issues arise that need to be reflected upon. The first one is that energy planning need not be based solely and exclusively on a country's own resources. In this way, it is possible to take place at regional level, being guaranteed through arrangements such as energy integration and/or cooperation, or even through international trade. The second issue is related to the concept of energy security, which, again, is intrinsic and often associated with national sovereignty and self-sufficiency.

Consequently, energy is seen from the point of view of planning and security, as, once again, issues intrinsic to sovereignty, *autonomy*, *independence* and *self-sufficiency* of States. In this sense, it is common to see the concepts of *energy security* as domestic policies and priorities in the national agenda (SANTOS, 2014b). Nevertheless, there is not even a clear consensus about the real meaning of such concept (JOHANSSON, 2012, SANTOS *et al*., 2017b).

Precisely for this reason, we seek to overcome this shortcoming rooted in the energy area itself. Thus, the proposal of this thesis is to discuss the theme from a regional logic, understanding that different countries can achieve their goals rather through strategic (geo)political arrangements with their neighbors. Accordingly, this thesis has a regional rationale, which highlights, believes, suggests and sees in regional integration an alternative to individual and state-centric management.

Notwithstanding, it is important to emphasize that regional integration is an extremely complex concept, misunderstood and instrumentalized by different countries. *Complex*, as it is discussed in the most different areas, such as Economics, Social Sciences, Political Science, History, Geography, International Relations and Law, for example, without any consensus about its real meaning. It is *misunderstood* not only by different interpretations and approaches, but above all because it is often believed that regional integration is synonymous of international trade. In this way, it is often seen as a strictly economic issue, which ends up obscuring its social, political, institutional, cultural and historical nature. Finally, it is a concept *instrumentalized by different countries* inasmuch as, in the absence of commitments inherent in participating of a regional arrangement, countries in some cases seek only short-term private gains, which risk the very process of regional integration.

Since regional integration is such a broad topic, the focus of the thesis is on *energy integration*. Fleeing mainstream approaches, it is not assumed that energy integration is an exclusively technical issue, but also a (geo)political, economic, institutional, regulatory, and diplomatic matter. It is a cross-cutting theme, which must be understood as a process (rather than an end itself) to achieve multiple benefits. In order to reach them, there must be *political will* of governments to prioritize projects and initiatives that promote regional energy integration, even by their already intrinsically domestic and strategic nature.

As an example, and avoiding any comparison that reproduces the idea that there is one way only to integrate, energy was the basis of the European regional integration process with the European Coal and Steel Community (ECSC), of 1951, and the European Atomic Energy Community (Euratom), of 1957. In the case of the current European Union (EU), although there was also the influence of nationalist perspectives on the energy agenda, the 'sense of possession' (DAINTITH and WILLIAMS, 1987) of energy resources was not enough for such resistance from countries to approach or even unify their energy markets[1]. Undoubtedly, the lower allocation of energy resources and vulnerability to external dependence reinforced this need to ensure regional arrangements capable of addressing the issue.

But the focus of this thesis is not the European countries, but those of South America. When it comes to regional electricity infrastructure releated to energy integration, South America is naturally a better option to consider. The region has the potential to become self-sufficient in energy, due to its wide variety of sources and the complementarity between them. In this sense, South American energy integration would allow countries to take advantage of the region's rich but unequally distributed resources, especially hydropower and natural gas.

[1] Although the European Union (EU) originated in the energy issue in the early 1950s, it is only in 2007 that the first 'Energy Action Plan'.

> In contrast to Latin America[2] as a whole, it consists, firstly, of a compact geographical and physically contiguous unit (…) Secondly, the region has extensive reserves of both renewable and non-renewable power that can be transformed into electricity (…) Third, South America has successful background in the field of energy infrastructure integration (BIATO *et al*, 2016: 63).

In this sense, and considering the South American subcontinent, where there are several regional integration initiatives, the particular focus of this thesis will be on the Southern Common Market (Mercosur), an initiative that dates back to the 1990s and initially counts on Argentina, Brazil, Paraguay and Uruguay. It should be noted that the current formation of Mercosur encompasses more than 70% of both population and territory of South America.

In this context, considering the fact that they are developing countries, the social dimension inherent to energy stands out. Because they are countries whose access to electricity is not always guaranteed to the entire population, especially in regions farthest away from major centers and rural areas, the guarantee and universalization of access to energy is of relevance in the energy strategy of these countries. Likewise, the region has geographical particularities such as the Andes Mountains Range, the Amazon Forest, the Atacama Desert and Patagonia Glaciers, which make it necessary to respect the geophysical and environmental constraints that are imposed on the region. Therefore, exploring regional integration as a means of guaranteeing basic rights[3], such as access to energy and respect for the environment, can be seen as an alternative and necessary development mechanism.

Another feature of the region is the continued increase in energy demand, either through greater access to energy services or through changes in the living, production and consumption habits of the population. The United Nations Economic Commission for

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[2] It is worth noting that in Central America there is the famous and successful Central American Electrical Interconnection System (SIEPAC) energy integration project. This infrastructure includes compensation equipment and substations extending over 1,800 km of 230-KW transmission lines, connecting 15 substations through 28 access bays. The SIEPAC line connects Panama to Guatemala, through Costa Rica, Nicaragua, Honduras and El Salvador, but is still far from realities such as Nordpool, Real-Time Energy Market (PJM) and Iberian Electricity Market (MIBEL). See **Appendix A**.

[3] Highlighted in the International Energy Charter at the Ministerial Conference (The Hague II) in 2015. CEIA and RIBEIRO (2016) stress that energy should be seen as a right, not as a commodity – since it can be considered as a key factor in achieving social justice (job creation, provision of basic social services, and better income distribution).

Latin America and the Caribbean (ECLAC) also highlights the urbanization of certain regions as one of the reasons why there is such an increase in energy demand. To meet this challenge, electricity is most adaptable to urban areas, given its form of control, use of appliances and ease of adapting it to transportation.

Therefore, countries in the region need to plan supply-side and energy-efficiency (EE) policies to deal with these pressures. However, although there are diversity and complementarity of resources, particularly energy resources, the region has paradoxically an unmet demand, with frequent supply crises in the Mercosur region and limited investments in energy infrastructure. Precisely because of this, the relationship between the existence of natural resources and the available energy is not direct, what poses more challenges to (regional) energy management and planning (DESIDERÁ NETO *et al.*, 2014).

Recently, there was the adhesion of Venezuela (2012)[4] to Mercosur and Bolivia's adhesion as a full member is ongoing. This *enlargement* of the bloc (an increase in the number of States Parties) is extremely interesting, especially when it comes to energy endowment. According to BP, Venezuela has the largest oil reserves in the world and already has regional energy projects such as Petrocaribe, Petroandina, Petrosur and Petroamerica. In turn, Bolivia has the regional experience of the Bolivia-Brazil Gas Pipeline (GASBOL) and, like Venezuela, has relevant hydroelectric potential and the possibility of creating international interconnections with neighbouring countries.

There are many justifications for this thesis. Unlike the context of the 1970s, when the price of oil increased with the 1973 and 1979 crises, the current global energy scenario is distinct from that of nearly half a century ago. The International Energy Agency (IEA) itself, in the 2014 *Medium-Term Coal Market Report*, draws attention to the significant increase in coal consumption, often justified by emerging economies, to the supply of shale gas, as well as to the discovery of new oil reserves (in addition to new exploratory techniques that allow for greater longevity of the 'black gold').

Against this, and in the face of the world logic, the sustainable development imperative and the promotion of access to clean and renewable energy lead to the need to implement

[4] At the end of the research period and elaboration of the thesis, the country ended up being suspended and kicked out from Mercosur. However, this situation is not yet clear or fully defined, which is the reason why Venezuela has remained in the analysis.

new policies and energy planning, incorporating new variables and objectives into the feasibility analysis of projects of energy infrastructure. It should be noted that energy has recently been chosen as a goal with its own identity among the sustainable development goals (SDG), and it is not only seen a means to achieve other goals like in the millennium development goals (MDGs). As a first step towards meeting these new challenges, the Sustainable Energy for All (SE4All) was formulated, which is a nonprofit organization working with leaders in government, the private sector and civil society to drive further, faster action toward achieving Sustainable Development Goal 7 (affordable and clean energy).

Although many studies discuss and use the concept of energy security to reach these energy goals, there is no consensus about its meaning, nor about the methodologies and variables used to analyze it. It is a broad concept, generic, context-dependent and therefore vague and often empty. Thus, it is an insufficient concept to analyze certain cases and regions.

Albeit it is a very widespread concept, few studies work with energy security in the face of a regional logic, mainly because of the influence of nationalist and state-centric perspectives that prioritize strategic energy studies. Consequently, little research, focusing on regional cooperation and integration as ways of ensuring energy goals, has been conducted so far. When they exist, they do focus on Organisation for Economic Co-operation and Development (OECD) countries.

With regard to Mercosur, it is often associated only with intra-bloc trade (among its members) and, although there are sub-working groups (SGTs) dealing with energy and environmental issues, little has been done and officially published about the region's energy planning.

As a direct consequence of the systematic absence of studies that overcome the national perspective, there are few critical comparative studies in the energy sector. There are no recent studies working with comparative energy policies within Mercosur to date. Actually, there are some studies that encompass Latin or South American countries, consequently they evaluate Mercosur countries, but they do not respect the official composition of the regional bloc.

Finally, the research is also justified by the inexistence of papers discussing regional energy integration, striving to promote a connection and a dialogue between contributions from areas such as economics, international relations and energy planning, considering, for example, economic, political, diplomatic, regulatory, physical, infrastructural, environmental. Although it may seem obvious, it is necessary to look at the theme in its entireness and consider its different facets and perspectives; otherwise, ignoring the cross-cutting nature of the theme will lead to partial, biased and limited contributions.

1.2 Objectives

Therefore, the general objective of this thesis is to analyze the issue of energy integration within the Mercosur countries, relating it to the suggested concept of *regional energy security*. By defining the scope of the thesis to Mercosur, the space and time analysis are automatically delimited. Regarding the area analyzed, it includes the original configuration of the block (Argentina, Brazil, Paraguay and Uruguay), as well as Bolivia and Venezuela; with regards to time analysis, the post-signing period of the Treaty of Asunción (1991) will be evaluated to date, what will serve as a basis for the creation of scenarios in energy modeling by 2050.

- Among the specific objectives, we can highlight;
- To review the evolution of the concepts of *energy security* and *regional integration*, pointing out their contributions and limitations;
- To propose the concept of *regional energy security* to analyze cases of regional integration/cooperation and/or regional blocs;
- To make a comparative analysis of the current energy reality of the Mercosur countries, highlighting national initiatives related to regional integration;
- To evaluate the evolution of Mercosur's regional energy security between 1990 and 2010, based on the set of own elaboration indicators that generate socio-environmental-energy security index (SEES index); and
- To create scenarios of regional electric integration, considering different premises and projects, to measure the impact of the promotion of regional integration on the need for new electric projects, in the expansion of installed capacity and generation, as well as in greenhouse gas emissions (GHG).

The originality of the thesis lies on many issues. The thesis deepens the dynamics of integration to the detriment of regional conflict, which itself is original and innovative – mainly because, as already mentioned, energy issues are often considered to be associated with autonomy, self-sufficiency and national sovereignties. In addition, and related to the previous argument, the proposal of problematization of the concept of energy security aims to deal with gaps that exist in the literature, although it is a widely accepted and reproduced concept. In suggesting the SEES index, we are not only (re)defining and offering a new approach to energy planning, but also associating it with the new environmental paradigm (NEP) (DUNLAP and VAN LIERE, 1978, GADENNE *et al.*, 2011).

Because it is a analysis of (part of) South America, it is not intended to indiscriminately apply the theories of regional integration that were created to understand the European case, such as the neo-functionalist – which basically focuses on the relevance of supranational institutions. In fact, intergovernmental theory will be used, which disregards this focus and highlights the greater autonomy and sovereignty of the countries involved in the process of regional integration.

With regard to the particular case of regional integration under analysis, it is worth noting that this is one of the first works that considers the initial formation of Mercosur (Argentina, Brazil, Paraguay and Uruguay), as well as Venezuela and Bolivia. Finally, it should be noted that the methodological design and the criteria of analysis are original and innovative, insofar as it aggregates different areas, such as international security, regional integration, sustainable development, public policies, as well as energy indicators/modeling. Thus, bibliographical research and theoretical development have influences from Economic Sciences, Political Science, International Relations, Security, Energy, Environment and Development, for example.

The assumption is that greater regional energy integration is better for the region, what will be ratified in different chapters and sections of this thesis. In addition, another assumption of the research is that Bolivia's effective accession process will be finalized, so that the country can be considered a Mercosur State Party. Finally, another assumption is that the electrical integration is the ideal case study to be analyzed in this thesis due to social benefits related to it.

1.3 Presentation of thesis structure and contents

Figure 1 shows the structure of its chapters. Note that chapters include quantitative and qualitative primary sources such as statistics, forecast data, norms, laws, international treaties, agreements, memorandum of understanding, regulatory frameworks, decisions, recommendations, decree, resolutions, framework agreements, declarations, programs and planning.

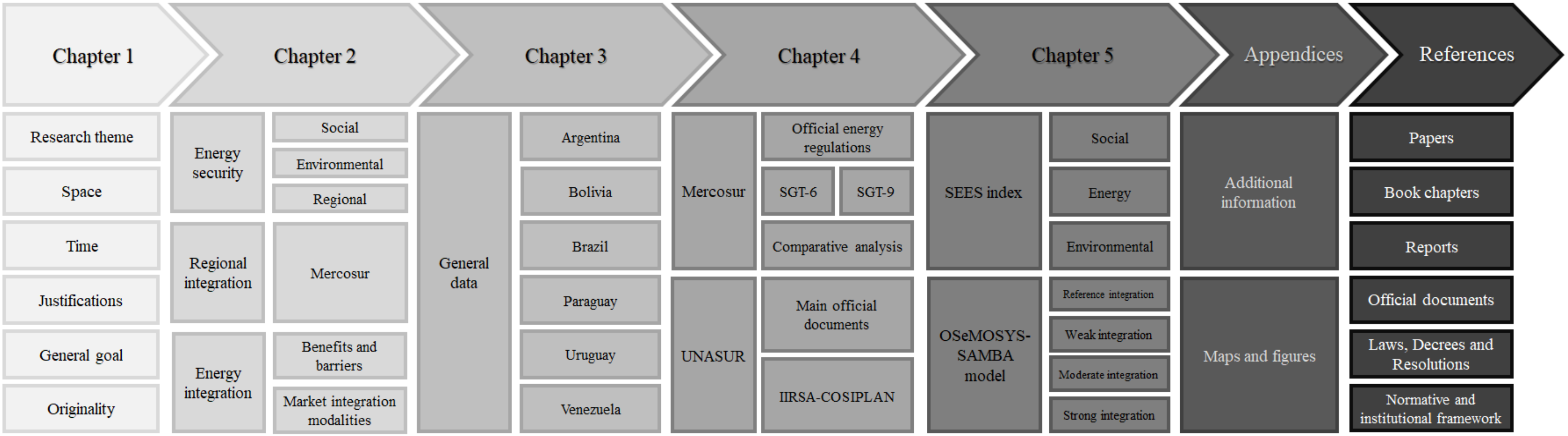

Figure 1. Structure of chapters

Source: Own elaboration

Chapter 1 is the introduction itself. It presents the theme of the research, as well as the boundaries to the space (Mercosur) and time of analysis (1990 onward), as well as methodology, justifications, general objective and originality of this study. It seeks to clarify to the reader the basis on which the thesis will be conducted, as well as the ontological (research nature), epistemological (perception of reality of research) and methodological (research techniques and methods) choices of the research.

Chapter 2 is subdivided into 3 sections, which constitute the 'literature review'. The quotes are due to the fact that this chapter is much more than a simple review of what has been discussed recently on the topics covered; in fact, it makes a critical and positioned presentation on the following topics: energy security (section 2.1), regional integration and Mercosur (section 2.2) and energy integration (section 2.3). Numerous papers, such as articles, reports and chapters of national and international books have been used as a basis for the main key concepts of this thesis. It is worth mentioning that the discussion about the concept of energy security is focused on three dimensions: social (subsection 2.1.1), environmental (subsection 2.1.2) and regional (subsection 2.1.3). Likewise, the debate on energy integration is subdivided into benefits and barriers (subseciton 2.3.1) and market integration modalities (subsection 2.3.2).

Chapter 3 presents qualitative and quantitative national data and analyzes the energy sector of the countries under study. The national and regional quantitative primary sources are databases such as World Databank, sieLAC, ECLACstat, CIER, COCIER, BP, WEC and national energy ministries. The chapter will be organized in two parts. The first one provides a comparative analysis of different primary quantitative data on energy power plants and international interconnections; private participation in generation, transmission and distribution; and gas pipeline network and natural gas reserves in the region, for example. The second part provides a comparative analysis on the energy sector of each analyzed countries: Argentina (section 3.1), Bolivia (section 3.2), Brazil (section 3.3), Paraguay (section 3.4), Uruguay (section 3.5) and Venezuela (section 3.6). There are information such as geographical and economic overview; structure of energy markets, separated by electricity, and oil and gas (O&G); summarized energy balance; binational projects, whether hydroelectric plants or gas pipelines; and international (cross-border) interconnections and international trade, for example.

Chapter 4 deals with the same topic from a regional perspective. It presents energy information in the framework of Mercosur (section 4.1) and UNASUR (section 4.2) on the basis of regional qualitative primary sources such as norms, laws, international treaties, agreements, memorandum of understanding, regulatory frameworks, decisions, recommendations, decree, resolutions, framework agreements, declarations, programs and planning. About 110 primary sources of Mercosur were consulted and analyzed, highlighting 25 Mercosur's official energy regulations (1993-2012), as well as 66 frequency of Mercosur' Sub-Working Group (SGT-6) Environment meetings (1996-2015) and 16 frequency Mercosur's of SGT-9 Energy meetings (2005-2011). Besides, 2 comparative analysis based on Chapter 3 are carried out: (i) a comparative analysis of electric power industry in Mercosur countries; and (ii) a comparative analysis of O&G industry in Mercosur countries. Concerning UNASUR, five main documents dealing with the energy issue are analyzed, such as the South American Energy Treaty (2010), as well as the last 10 IIRSA-COSIPLAN reports in order to identify the relevance of energy projects in terms of participation in the number of projects and amount (US$ million).

Chapter 5, as well as the two previous ones, will also be divided into two main sections: SEES index (section 5.1) and Scenario modeling (section 5.2). In the first section, it is created a new hybrid index called socio-environmental-energy security (SEES), whose main objective is to analyze the evolution of Mercosur energy policies in the past (1990-2010). Then, the second section proposes energy scenarios 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, whose objective is to analyze present and possible integration scenarios in the future (2015-2050). It is divided into two subsections, which present the key assumptions (subsection 5.2.1) and the results (subsection 5.2.2) achieved by every modeled scenario: reference integration scenario (RIS), weak integration scenario (WIS), moderate integration scenario (MIS) and strong integration scenario (SIS). They consider expansion and new international interconnection lines, new binational hydroelectric plants, new contractual arrangements (swaps) as well as regulatory harmonization.

Finally, **Chapter 6** presents the main conclusions of this thesis, as well as some recommendations. It seeks to summarize its main findings, highlighting the need to review regional policies on regional energy integration, including the results in the light of the models used. Thus, it seeks to clarify the main points related to regional integration associated with the energy issue in order to contribute to reduce confusion in the literature and, consequently, to the decision making of the matter in question. **Appendices** with additional information (figures, tables, and maps) are then displayed. Finally, **References** that supported the thesis are presented.

2. Energy security and regional integration

This chapter is more than a simple 'review of the literature'. As highlighted before in the Introduction (**Chapter 1**), an effort is made to combine different approaches and perspectives where dialogue is often non-existent, also in order to clarify the theoretical foundations essential to the main debates proposed by this thesis. Ergo, we cite authors from Economic Science, Political Science, International Relations, Energy Planning[5], Energy Engineering and Environmental Sciences, for example.

More than just presenting a diversity of texts, reports and papers that deal with the subject in the last years, this chapter incites debate and reflection. It presents not only the main concepts but also their evolution over time, as well as their inconsistencies. In addition, at the end of each section and subsection, the author's position on the subject is clearly marked so that the reader understands the path through which the text is being conducted.

In this way, this chapter is divided into three sections. The first section deals with Energy security (section 2.1), presenting the evolution of the concept, based on the context of the 1970s oil shocks. There are three subsections that highlight the relevance of incorporating into the analysis social (subsection 2.1.1), environmental (subsection 2.1.2) and regional (subsection 2.1.3) dimensions. This section is particularly important because it will create the conceptual bases that will justify the creation of the SEES index (subsection 4.1), to be detailed later.

The second section deals with the concept of regional integration (section 2.2), focusing in particular on the Mercosur case. The section highlights the need to promote an interdisciplinary approach to the issue, addressing and facing the complexity it demands. A brief presentation of the historical process of creation and consolidation of Mercosur is presented, finally introducing some data that show the regional asymmetries and intra-bloc inequalities (within the bloc) that exist and that consequently need to be considered in studies, projects and policies designed for the region.

Finally, the last section deals specifically with energy integration itself (section 2.3). Being then split into two subsections, the first one deals with the benefits associated with

[5] To access Energy Planning contributions, see CHEVALIER (1973), HELM (2002, 2011, 2014), MARTIN (1974, 1988, 1990, 1992, 2000), PERCEBOIS (1986, 2008),

promoting energy integration, as well as its main barriers (subsection 2.3.1). Following are different market integration modalities (subsection 2.3.2), which are then subdivided into binational plants (HPP), interruptible flow (opportunity interchange), firm energy contracting (flow per firm contract), market coupling (loose volume coupling, tight volume coupling and market splitting. It is a more technical subsection, based on legal, commercial and regulatory framework, which is too little addressed in the regional energy integration literature for South American countries[6].

2.1 Energy security[7]

There are various approaches to dealing with energy security. For BUZAN *et al*. (1998) and WÆVER (1995, 1998), the security approach generally manifests itself through the following three steps: (i) threat identification; (ii) emergency action proposal; and (iii) breaking free of regular rules of security. Ergo, 'it is by labelling something [as] a security issue that it becomes one' (WÆVER, 2004: 13), so the securitization becomes 'a social and intersubjective construction' (TAURECK, 2006: 3).

The concept of energy security comes typically from the 20th century, more precisely from the period of the oil shocks, when the central concern of the period was the reduction of dependence on oil imports, particularly in OECD countries (SANTOS, 2015, UNDP, 2009, VIVODA, 2010, YERGIN, 1991). The academic debate ended up weakened with the stabilization of the oil price (1990s), but it again played a leading role in the countries' strategic agenda, in particular due to the increasing demand in Asia, the interruptions in gas supply in Europe and the decarbonisation of energy systems (CHERP and JEWELL, 2014, CHESTER, 2010, HANCOCK and VIVODA, 2014, YERGIN, 2006).

In fact, price and guarantee of demand from primary sources such as oil and gas strongly influence the literature on energy security (ANG *et al*., 2015, CHESTER, 2010, IEA, 2013, ISBELL, 2007, JAMASB and POLLITT, 2008, MULLER-KRAENNER, 2008, SPANJER, 2007, UNDP, 2004, WESLEY, 2007). However, energy security is not

[6] On the other hand, it is common to find studies and projects that evaluate these modalities analyzing different existing European cases, as in BAUMANN (2014) and CRETI *et al*. (2010).

[7] This section comes from a paper published in Energies, December 2017. See: SANTOS *et al*., 2017b, "Evaluating Energy Policies Through the Use of a Hybrid Quantitative Indicator-Based Approach: The Case of Mercosur", *Energies*, v. 10, n. 12 (Dec), pp. 2140-2155.

limited to this. Therefore, it is essential to understand the concept, especially because it presents a dynamic definition and dimensions that evolve as circumstances change over time. 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).

VAN DER HOEVEN (2011) reaffirms this argument, arguing that promoting energy security means mitigating risks and managing the uncertainties related to the future of energy markets. To that end, KUCHARSKI and UNESAKI (2015) stress that it is necessary not only to define the energy system but its components and behavior in order to perceive its vulnerabilities, risks and threats, suggesting the adoption of the complex adaptative systems (CAS) approach.

However, according to CHERP and JEWELL (2014) the energy security concept should take into account three main issues: 'security for whom?', 'security for which values?' and 'security from what threats?'. Relating it to the concept of securitization, the authors evaluate how the approach of 4As (availability, accessibility, affordability and acceptability) influences the understanding of these issues. In raising such questions, the authors guarantee a more critical reflection of the concept itself, as it makes room for an analysis of the actors (consumers and producers), values and threats.

KRUYT *et al*. (2009) emphasize that there are four main elements in the understanding of energy security, which are: (i) availability of energy; (ii) accessibility; (iii) costs; and (iv) environmental sustainability. VON HIPPEL *et al*. (2011) also highlight four variables that need to be incorporated into the concept, namely: (i) environment; (ii) technology; (iii) demand side management; and (iv) sociocultural factors.

Thus, it is clear that there are several interpretations and understandings about the concept of energy security, which has undergone changes since the 1970s. In nearly 50 years, the International Energy Agency (IEA) has had to incorporate these changes into its own definitions of energy security. In 1985, it is defined as 'an adequate supply of energy at a reasonable cost' (IEA, 1985: 29); in 2007, however, it is stated that 'energy security always consists of both a physical component and a price component, (but) the relative importance of these depends on market structure' (IEA, 2007: 32). It is only in 2010, however, that its definition includes ‘while respecting environmental concerns’ (CHERP and JEWELL, 2014).

Today 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 promptly react to sudden changes in the supply-demand balance.’ (IEA website).

Ergo, it is clear that the environmental and investment question would be exclusively for the long-term analysis, while the short-term ones focus on the mismatch between supply and demand.

The World Energy Assessment stresses that energy security is more than just ensuring the availability of abundant oil reserves at affordable prices, highlighting the need to analyze the long-term in face of a new economic environment and the promotion of sustainable development (UNDP, 2000). SIMS *et al*. (2007) show the relevance of innovative supply-side technologies, which, by allowing new technologies to become commercial and competitive, will make it possible to promote the participation of clean energy at local, regional and global levels. ‘Technology innovation efforts will need to be complemented by new market designs, new policies and by new financing and business models, as well as technology transfer’ (IRENA, 2017b: 13).

With regard to the definition of the concept of energy security, there is a significant tendency to present indicators to evaluate it. VON HIPPEL *et al*. (2011), VIVODA (2010) and SOVACOOL (2011), for example, use this methodology to measure and compare the evolution of energy security in the most diverse countries. In turn, LÖSCHEL *et al*. (2010) are the first authors to suggest a differentiation between ex-ante and ex-post indicators.

As in TONGSOPIT *et al*. (2016) and YAO and CHANG (2014), the concept of energy security has evolved over time, addressing new issues such as efficiency, international relations (cooperation or energy integration), environmental protection and institutional dimensions. The contemporary scope of the concept goes beyond the OECD oil importers as a proxy for the definition, emphasizing the role of non-state actors, from individual economies to global production networks (BRIDGE, 2008, CHERP, 2012).

In this sense, there is no consensus on the concept and, consequently, on energy policies, which vary from energy poverty to climate change (CHERP and JEWELL, 2014). Therefore, it is not possible to have a single defined and accepted concept about energy security. Ergo, CHESTER (2010) and VIVODA (2010) define that it is a slippery concept, that is, hard to define universally, because it is polysemic, multi-dimensional and context-dependent on the nature of each country/region.

ANG *et al*. (2015) provide an exhaustive analysis of 104 studies on energy security (peer-reviewed journals, national agency reports, international organizations, and business/professional associations) since 2001. They also assess whether a particular definition is given to the concept of energy security and/or if there is an indicator to evaluate it, as well as if it takes into account infrastructure, prices, social effects, environment, governance and efficiency. They perceive that the average number of studies per year increased during this period and that the percentage of qualitative and quantitative studies is very similar, with no evidence that the subjects considered in both groups are different.

The authors state that of the total of the studies analyzed, 80% present definitions on energy security, without a broad acceptable consensus. Once again, it becomes clear that it is a highly context-dependent concept, so there are sporadic references to the concept in an abstract, vague and unfocused way (CHESTER, 2010, ANG *et al*., 2015), which reinforces the argument that there is no unifying methodology to the energy security assessment (TONGSOPIT *et al*., 2016).

In light of the evolution of the concept of energy security, as well as the complexity of meanings and methodologies, it is necessary to understand three significant differences when it comes to this subject:

- **Classical vs. Contemporary studies**: in the 1970s and 1980s, energy security basically meant the stable supply of cheap oil under threat of embargoes and price manipulation by exporters (CHERP and JEWELL, 2014, YERGIN, 1988). In this sense, the concept was very close to national values such as political and economic independence, territorial integrity, sovereignty when formulating policies, and self-sufficiency in oil. On the other hand, contemporary studies on energy security incorporate a number of other factors, taking into account climate change mitigation, regional agreements, equitable provision of energy services, socio-political stability, climate change and, in general, promoting sustainable development (CHERP *et al*., 2014, 2012, GOLDTHAU, 2014, YERGIN, 2006);

- **Developed vs. Developing countries**: ANG *et al.* (2015) and KANCHANA and UNESAKI (2014) emphasize the need to take into account the profile and socioeconomic status of countries when analyzing the concept of energy security. For more developed countries, the concept represents a resilient energy system with uninterrupted availability of energy sources at an affordable price (WINZER, 2012) – even for less developed countries, it can be understood as access to modern energy services (UNDP, 2011). MARTCHAMODOL and KUMAR (2012: 653), however, 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’. In fact, it is in the developing countries where there are the majority of energy-intensive industries producing goods (SANWAL, 2010, 2012, 2014), but despite this transition, it is still possible to find energy-intensive industries in certain developed countries. Precisely because of the focus of the analysis being on developing countries, such a distinction is fundamentally important, since they will be responsible for the largest increase in emissions in the future (SCHÜLLER, 2012); and
- **Short-term vs. Long-term analysis**: generally, in the short and medium-term, energy security focuses on the impacts of price shocks or unanticipated supply disruptions, as well as on operational failures; but in the medium-term the promotion of renewable energies (RE) can be considered to deal with dependence on oil (KUCHARSKI and UNESAKI, 2015). On the other hand, in the long-term it is mandatory to consider the demand profile, infrastructure, depletion of reserves, technological innovation, climate change, adaptability of systems, and other variables (KUCHARSKI and UNESAKI, 2014, SMIT and WANDEL, 2006). KISEL *et al*. (2016) suggest that the analysis should be divided into short and long-term; for them, in the short-term, energy security can be basically

measured by the potential that the energy system has to deal with disturbances (operational resilience), while in the long-term it is necessary to consider (i) technical resilience and vulnerability; (ii) economic dependence; and (iii) political affectability – oscillations to (geo)political influences. It is important, however, to understand that energy policies that may lead to increased energy security in the short-therm may not guarantee it in long-term (ANG *et al*., 2015). In the past, for example, several projects have ensured short-term energy security, assumed as a guarantee of supply, without necessarily considering their social and environmental impacts. Itaipu Binacional, energy integration project through binational dam between Brazil and Paraguay of the 1970s, is an example of such reality.

In making these considerations, it is necessary to highlight the analysis of the concept of energy security in the different countries and regions, associating it with the approaches that fully consider their impacts on social, economic and environmental variables. This proposal is in line with the argument of the former Secretary-General of the UN, Ban Ki-Moon, who, taking into account the sustainable development agenda, stated that 'the problems we face are interdependent. Poverty, hunger, insecurity, climate change, environmental degradation, energy scarcity – these challenges demand holistic and integrated solutions' (UN NEWS CENTER, 2013). In this way, nothing more appropriate than treating the subject in an interdisciplinary and integral way. In addition, it is fully in line with the targets of the sustainable development goal 7 (SDG 7), that seeks to ensure access to affordable, reliable, sustainable and modern energy for all.

In this sense, the following subsections will stress the challenges to be incorporated into energy policies, especially when it comes to the analysis of energy security in developing countries. At the same time, beyond the social and environmental dimensions, there is a discussion on the benefits of promoting energy security at the regional level, which challenges the mainstream national logic of addressing the issue. It is thus suggested an innovative and alternative approach to current policies for the promotion of energy security, taking into account new dimensions (social and environmental) in the face of a new (regional) approach.

2.1.1 Social dimension

In particular, when analyzing developing countries, it is essential to take into account regional and national inequalities and asymmetries. Critics have already drawn attention to social inequalities when using energy indicators for certain regions (TONGSOPIT *et al*., 2016)[8]. To CHERP and JEWELL (2014), for example, a central issue in contemporary studies of energy security is precisely to identify and explore the relationships between energy systems and social values.

For developed countries, sustainability focus almost exclusively on environmental issues, while issues such as poverty and equity are fundamentally important and urgent in developing countries (KEMMLER and SPRENG, 2007). Ergo, considering social indicators is essential for developing countries, such as those related to energy poverty (PEREIRA JÚNIOR *et al*., 2008, SANTOS *et al*., 2017a, VERA and LANGLOIS, 2007).

It is therefore clear that energy indicators are not limited exclusively to energy issues themselves. VIVODA (2010) argues that human security is among the challenges that need to be incorporated into the new concept of energy security, emphasizing that the conceptualization of energy security must consider the provision of basic energy services such as access to electricity.

ANG *et al*. (2015) highlight the relevance of social issues in countries where energy poverty or connectivity is a major concern. In the analysis of the Greek energy system, ANGELIS-DIMAKIS *et al*. (2012) use three indicators to analyze the social dimension (percentage of households with access to commercial energy sources, percentage of household income spent on energy, and share of household expenditures on energy for each income group). According to IRENA (2017b), it is worth emphasizing that the approach to this suggested energy transition could fuel economic growth and create new employment opportunities. Once again, the relationship between the social and energy dimensions is clear and real.

[8] Consumers are the weakest link in the energy chain.

2.1.2 Environmental dimension

Some authors take into consideration the issue of environmental impact in understanding the concept of energy security, as often seen in the analysis of developed countries or in the medium/long-term general analysis. However, what is 'environmentally acceptable' varies among different actors, such as local people, environmental non-governmental organizations (NGOs), industries, and nation states (CHERP and JEWELL, 2014).

The APERC's (2007: 6) definition on energy security is 'the ability of an economy to guarantee the availability of energy resource 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'. CHESTER (2010), CHEVALIER (2006), HUGHES (2012), KANCHANA and UNESAKI (2014), KRUYT *et al*. (2009), KUCHARSKI and UNESAKI (2015), TONGSOPIT *et al*. (2016) and WINZER (2012) are some of the authors who also consider the environmental and climate change impacts on energy systems in their studies.

VON HIPPEL *et al*. (2011) emphasize the need to reformulate energy security policies in order to allow them to deal with environmental issues such as climate change and global warming, which may represent one of the main challenges to the traditional (classical perspetive) thinking of energy security. ANG *et al*. (2015) argue that sustainability and environmental issues are directly related to energy security, due to emissions that contribute to global warming, air pollution and other risks such as forest flooding and oil spills.

The EUROPEAN COMMISSION[9] (2001) and PASQUALETTI and SOVACOOL (2012) also stress the need to incorporate environmental concerns into energy security. In developing an energy security index, SOVACOOL (2013) also includes environmental sustainability as a dimension of energy security, considering indicators such as land use, water, climate change and pollution.

As ANG *et al*. (2015) highlight, the weight 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. They evaluate that in recent studies the

[9] Environmental protection has been an important part of the European Union's (EU) energy policy since its inclusion in the Single European Act of 1986 (LANGSDORF, 2011).

environmental dimension occupies the second area most addressed, only behind the economic one; in turn, the social aspects occupy only the fifth position, behind 4As and energy supply.

Moreover, the authors perceive that the weight of both themes varies greatly between official reports, journals and other publications; the environmental theme is cited in about 40% of journals and only about 15% of official reports; in turn, the percentage of social agenda is 30% and 40%, respectively. Ergo, it is noteworthy to reinforce how the different sources attribute different weights to the same variables, which once again ratifies the lack of consensus on the concept of energy security.

With regard to the current global value chains (GVC), with extraction, exploration and production of a country fragmented in other countries and/or continents, it is essential to consider the argument of common but differentiated responsibilities (CBDR).

In addition, OBANI and GUPTA (2016) emphasize the need to consider the current economic recession in major economies in the North, which has several impacts both domestically and internationally. At the same time that it reduces the anthropogenic emissions of greenhouse gases (GHGs) in the short-term, it can increase it in the medium/long-term associated with their recovery. Due to the uncertainty as to the net result of these movements, as well as to the current scenario of international crisis, many researchers are studying the effect of the recession on global climate change policy (SHUM, 2012).

It is also worth noting that developing countries are often even more vulnerable to environmental pollution due to weak environmental institutions and laws, population growth, and poverty (LYNCH *et al*., 2017). In addition, such vulnerability is aggravated because they have less access to funding for their development needs.

2.1.3 Regional dimension

Indeed, as CHERP and JEWELL (2014) argue, YERGIN's (1988) classic definition of energy security does refer to the idea of a purely national concern. This influence, present in the mainstream of economics and international relations (IR), shaped this issue to become a priority of the national agendas of each country. In this way, they represent state-centered definitions of the concept of energy security.

Moreover, there is a clear influence of a market-centric definition, which 'is clearly based on the pure Walrasian market with its self-equilibrating properties. Markets are assumed to be cleared through price adjustments' (CHESTER, 2010: 892). This approach assigns a limited role to States, a challenge that needs to be revised and overcome.

Therefore, another challenge that should be incorporated into the new concept of energy security (contemporary perspective) is the consideration of the international question, since 'energy security policies must also address international (regional and global) implications of energy security challenges' (VIVODA, 2010: 5259). In fact, as stressed by ANG *et al*. (2015), CEIA and RIBEIRO (2016), DEPARTMENT OF ENERGY AND CLIMATE CHANGE (2006), GOLDTHAU and SOVACOOL (2012) and SANTOS and VARELA (2016), countries have increasingly engaged in foreign policy and energy diplomacy[10] to ensure national energy security from different arrangements with exporting countries – often neighboring countries.

Ergo, there are few detailed studies on regional[11] energy security rather than national energy security, although it is widely known that 'interconnections of neighboring grids (electricity and gas networks) into regional grids greatly enhance energy security' (UNDP, 2000: 130). Besides, promoting regional energy security reduces costs and ensures a more efficient use of reserves and electricity.

However, TONGSOPIT *et al*. (2016) and KANCHANA and UNESAKI (2014) are some of the few authors who have quantitative studies measuring the evolution of regional energy security, in the specific case of the Association of Southeast Asian Nations (ASEAN). Thus, it is mandatory to stress the need to incorporate the regional approach in energy security studies, given their collective benefits. For the region of South/Latin America, the work carried out by CIER (2010) and MOURA (2017) stand out.

[10] There is no consensus on what the concept actually means. It is mostly used in the geopolitics debate on access to resources and points to a strategic and instrumental use of foreign policy to secure a country's energy supplies (GOLDTHAU, 2010). Energy diplomacy phenomenon is nothing new, but has emerged as a powerful concept in public discourse.

[11] There are fewer studies when dealing with regional agreements/blocs, although there are some that deal with certain pre-determined regions such as Europe, Latin America, OECD countries, Southeast Asia, among others.

This increased interdependence between producer and consumer countries makes the classical definition of energy security more challenging. VAN DER HOEVEN (2011) emphasizes the importance of energy integration in improving performance and reducing uncertainties, even though the author does not make a proper distinction between this policy strategy and the international trade of different energy sources. CHESTER (2010) points out that in the 21st century access to different energy sources depends on a complex system of global markets, vast cross-border infrastructure, and interdependencies with financial markets and technology, given the inability of countries to be self-sufficient.

JERVIS (1978), for example, defines that the security of one state reduces the security of another. Consequently, in view of this 'security dilemma', which can also be applied to the world of energy, it makes sense to rethink an approach to ensure increased regional energy security. VIVODA (2010) disagrees that the gain of energy security of one state necessarily represents the loss of others, but also highlights the relevance of the regional approach remains fundamental. This approach is consistent with KEOHANE and NYE's (2001) argument, which suggests the creation of institutions in order to reduce transaction costs and promote gains in international cooperation.

Notwithstanding, CHESTER (2010) and SANTOS *et al*. (2016a, 2016b, 2016c) highlight the risk of political instability when one thinks of regional energy security, as occurred with the interruption of gas supply in GASBOL[12] (between Bolivia and Brazil) and more recently in Europe[13] (Russian gas). It is worth mentioning that hindering or refusing to sell energy to importing countries is often referred to as 'energy weapon' (LÖSCHEL *et al*., 2010).

Relating the environmental area to the regional level, LIU, WU and HUANG (2017: 152) argue that 'climate change can not be addressed without global cooperation and action, which in turn depends on an equitable distribution of responsibility'. SANWAL (2012)

[12] There was nationalization of Bolivian hydrocarbons (oil and natural gas) by Decree n. 28,701/2006 ('*Héroes del Chaco*'), signed by former-president Evo Morales. The case included military occupation of the refineries, including those of Petrobras, under the allegation that foreign companies earned a lot and paid little to the Bolivian state. This event led to a crisis in the relationship between Brazil and Bolivia, especially since the former imported Bolivian gas since 1999 through GASBOL.

[13] The European case, as well as the South American one, highlights the vulnerability of the energy security of the countries to the need to import energy. About 65% of the gas consumed by the European Union (EU) countries is imported, whose almost half come from Russia – and much of that total has to pass through Ukraine. Events of disruption in the supply of Russian gas to the EU have already occurred in 2009 and 2014, but more recently the geopolitical crisis following the annexation of the Crimea by Vladimir Putin has led the EU to review its dependency situation by considering the import of liquefied natural gas (LNG) from the Middle East or US shale gas.

emphasizes that international cooperation was first suggested only in 1972 during the World Summit on the Human Environment held in Stockholm. In this sense, such authors rightly defend the need to consider regional cooperation and integration to achieve sustainable development, which is particularly true for developing countries.

With this section, we hope to have made it clear that the concept of energy security is time-dependent, space-dependent, fits almost everything and has been (re)framed since the 1970s. It then represents an old-fashioned, context-dependent and unreliable concept, but at the same time it has played and continues to play in some contexts an important role in energy policy[14]. As the focus of the thesis precisely relies on developing countries in the South American subcontinent, particularly Mercosur, the need to take into account social, environmental and regional dimensions stands out.

Social dimension, because in these countries a significant part of the population does not even have access to electricity, especially in the most isolated and/or rural regions. In addition, it is important to consider the increase in energy demand in certain countries (due to a more energy-intensive industrial and residential consumption), what urges the need to offer and guarantee universal access to energy, a proposition understood as human right. *Environmental dimension,* due to a series of international conventions, such as the recent Paris Agreement and SDG 9, there is a growing need to reduce the use of non-renewable fossil fuels and to mitigate CO_2 emissions. Thus, including both social and environmental dimensions highlights the close relationship between energy security and sustainable development.

Regional dimension has done the link between energy security and regional integration, because both concepts have in their nature the nationalist and state-centric characteristics. In this way, the thesis proposes an alternative approach to state-centered policies, rooted in concepts as state sovereignty, energy self-sufficiency and domestic energy planning. Undoubtedly, the consideration of these three dimensions does not exclude the relevance of the economic one (traditionally embedded in the concept of energy security).

[14] Our objective is not to deny the relevance of the concept, but to present its evolution and its limitations to discuss the theme in question. In this sense, our idea is to propose the concept of *regional energy security* and, to this end, chapter 5 will evaluate the evolution of Mercosur regional energy security since its formation through the creation of SEES index and OSeMOSYS-SAMBA modeling.

2.2 Regional Integration and Mercosur

The main goal of this subsection is to emphasize the time and space of this analysis. Instead of analyzing this issue from the perspective of a country (state), here an analysis concerning a group of states (regional blocs) will be carried out. For this purpose, it is necessary to make some reservations to the concept of regional integration, as well as to the consequences coming from its multiple interpretations.

First, it is important to highlight the existing confusion in the literature (even the specialized one) about the real sense of *regional integration*. Economic Science, Political Science, Social Sciences, International Relations, Geography, History and Law, for example, have dramatic ontological, epistemological and methodological differences to address the issue. Thus, for some it is a question of borders only, while for others it is a trade agreement, or common social rights/identities, or free transit of people and goods/services, or even legal harmonization.

In addition, most of the studies on the subject present a state-centric bias, i.e., it analyzes the cases identifying in the countries (States) the only relevant actors in the process (LACHER, 2003). Although this approach is limited, as there are other equally important actors in the different decision-making processes, such as organized civil society, non-governmental organizations (NGOs), public and private companies, it ends up prevailing in the different studies and works mainly for the ease of access to data and information[15].

In accordance with ECLAC (2009:1) [emphasis added], 'regional integration is the *process* through which different national economies seek mutual benefits, complementing themselves mutually' and it can be divided into three distinct categories: (i) economic and commercial integration; (ii) political integration; and (iii) physical integration[16].

There is a long literature that discusses the concept, policies and practices of regional integration. In advance, it is worth noting that this literature is influenced by a Eurocentric vision of the consolidation process of the current European Union (EU) (SÖDERBAUM,

[15] To some extent, although **Chapter 3** deals with subnational issues, the focus of the thesis analysis is statecentric, so that comparisons can be made with the other studies available in the literature.

[16] The existing debate on the relationship between 'economic/comercial'', 'physical', and 'political' integration is deep and interdisciplinary. However, the focus of this project relies on the last one, since it is the one less present in the literature and because we believe that debates envolving physical integration is impregnated by political and economic factors (too).

2013), as well as being different from the one that discusses international cooperation[17], a concept that is often used as a synonym for *regional integration*. Specifically regarding Latin American literature, especially in South American countries, the role played by presidents is often highlighted (PALESTINI and AGOSTINIS, 2018).

It is clear that integration is a process from the beginning, that is, it is not an end in itself. Therefore, it is a governance arrangement that allows a group of states to reach an end goal. ‘Regional integration can be understood as a multifaceted process through which the promotion of common and joint policies in a given region is aimed at reducing the region’s asymmetries and inequalities, as well as promoting socioeconomic well-being.” (SANTOS and DINIZ JÚNIOR, 2017: 23).

Despite the third category listed by ECLAC (2009) being less discussed in the current literature, it is important to note its intense relationship with the other ones, as well as its direct impacts on socioeconomic development of countries involved in the process of regional integration. Therefore, this thesis focus on this ‘traditional type of integration’[18], that is, physical integration, exactly due to this specificity, even because the discussions on infrastructure investments take place at this level and such investments pave the way for structural and significant changes in an economy.

However, it is necessary to limit the goals of this research, in order to taper off the topic to be studied, and as a result, to ensure a great deal of detail in this analysis. In this sense, within the range of physical integration, there are three main sectors: (i) transportation; (ii) communications; and (iii) energy. Since ‘energy’ is transversal to all other sectors mentioned, it is worth making it the target of this research, also due to its externalities experienced by other sectors of a given economy – such as lowering the cost and price of energy for the industrial, residential and service sectors.

Besides, the theoretical mainstream on regional integration in South America focus almost exclusively on the commercial issue and considering this fact we will not focus on it. Among the most cited works[19], BOHARA *et al*. (2004), BUSTOS (2011), YEATS

[17] Regional integration is more related to a long-term project, whose central objective is to promote collective well-being, reducing regional asymmetries. See BÖRZEL (2016).
[18] Unlike the mainstream approach of the theme of physical integration, (geo)political, social, economic and environmental variables will not be ignored.
[19] The research was carried out based on the texts mentioned and, of greater relevance, through the Web of Science, taking into account the keys “MERCOSUR” and “*MERCOSUL*”.

(1998), OLARREAGA and SOLOAGA (1998), LEIPZIGER *et al.* (1997) and FRANKEL *et al.* (1995) accentuate, once again, only transactions and commercial policies as proxies for the bloc integration. BOND *et al*. (2001), for instance, draw a direct line between deepened regional integration and multilateral trade agreements. VENABLES (2003) and PUGA (1999), similarly, address only commercial issues when they, in reality, refer to regional integration[20]. In this thesis, this approach will not be followed.

The Common Market of the South (Mercosur) was founded in 1991 through the Treaty of Asunción (TA), being driven by Brazilian and Argentinian then Presidents Fernando Collor de Mello and Carlos Menem, respectively. Their main goals were to build up a common market[21] between Argentina, Brazil, Paraguay and Uruguay. Notwithstanding, it is still worth noting that Mercosur is a direct consequence of a series of old bilateral agreements between Brazil and Argentina, the return of democracy and liberalization environment (MECHAM, 2003, SANTOS *et al*., 2016d). It refers to the concept of the Latin American Free Trade Association (LAFTA), created in the 1960s, whose successor, the Latin American Integration Association (LAIA), was founded in the 1980s.

By signing the Treaty of Asunción (TA)[22], the idea was that a free-trade zone (FTZ) would have already been established by the end of 1994 so that, subsequently, a customs union could be established as well through progressive trade liberalization. In reality, it is known that intra-bloc trade had significantly increased. The most immediate antecedent of this block formation was the Brazil-Argentina Integration Act signed in 1986 between Presidents José Sarney (Brazil) and Raúl Alfonsin (Argentina). Both of them were the first presidents of their countries after the end of dictatorial regimes. This Act gave birth

[20] It is noteworthy that the majority of the (most accessed) works on Latin/South American regional integration date back to the 1990s and early 2000s when the theme was a regional priority. There is also evidence of the diversity of calls for papers and journals that insist on this limited relationship between regional integration and trade, such as the 'Integration and Trade Journal' of the Inter-American Development Bank (IADB).

[21] For BALASSA (1961), there would exist a *steps* notion in order to deepen regional integration, and it would begin with a Free Trade Zone (FTZ), then it would come a Customs Union, followed by a Common Market and, last but not least, an Economic and Monetary Union would take place. However, as indicated by BERNAL-MEZA (2008), when it comes to Mercosur, it is often associated to an imperfect Customs Union.

[22] See: http://www.mercosur.int/innovaportal/file/719/1/CMC_1991_TRATADO_ES_Asuncion.pdf.

to the Program of Integration and Economic Cooperation (PICE) that largely influenced South American integration policy (ARAÚJO, 2012).

Afterwards, the Treaty of Integration, Cooperation, and Development between Brazil and Argentina was signed in 1988. An important decision adopted in the Protocol of Ouro Preto (POP)[23] was the recognition of the international juridical personality of MERCOSUR. This recognition gives to this economic bloc the competence to negotiate, on its own behalf, agreements with third parties, groups of countries and international organizations.

Mercosur is frequently interpreted from this intergovernmentalist theory, since institutions at state level prevail, that is, a bloc with no (or few) supranational character. In this scenario, states resist to the definition and creation of top-down policies, what gives them higher autonomy when establishing their own domestic policies.

> '"The absence of any supranational procedures keeps nation states as the sole locus of sovereignty" seems appropriate here and presents limits to the application of the governance model to Mercosur. In most cases, the institutions at stake are purely intergovernmental, rather than supranational, and function according to the principle of unanimity, thus lacking the autonomy and independence that their European counterparts enjoy' (ALMEIDA MEDEIROS, 2004: 93).

It is still worth noting that the geopolitical[24] and historic context of that period is very unusual, impacting the institutional and regulatory framework of the bloc. The countries of the region had back then used a model of Import Substitution Industrialization (ISI) in a political scenario of national dictatorships. In this sense, the Washington Consensus in the 1990s, as well as the redemocratization of the economies, led Mercosur to be known as a model of 'open regionalism' (DOMINGUEZ, 2007, MECHAM, 2003, HIRA, 1998, ECLAC, 1994).

This means that despite having interest in strengthening the relationship with neighboring countries, the countries were simultaneously interested in taking advantage of expanding international flows (trade and investment) above all, as a means of economic recovery

[23] See: http://www.mercosur.int/innovaportal/file/721/1/1994_protocoloouropreto_es.pdf.
[24] To deepen the relationship between geopolitics, natural resources and energy, see BRUCKMANN (2016), RODRIGUES (2016), SENHORAS *et al*. (2009), BECKER (2004) and KLARE (2001).

after the "lost decade" (1980). As a consequence, the 1990s saw the spread of free market economics and democracy, not least in Latin America, where military governments dissolved. Countries began dismantling state structures, privatizing, deregulating commercial and financial activities, and opening up their economies. This movement was accompanied by technological and communications advances, allowing integrated global product and factor markets to emerge through the movement of goods, services, capital and even labor (MECHAM, 2003).

This brief introduction on the bloc formation is basically to contextualize the main goal of this research, since it is not part of its scope to detail the historical formation of Mercosur. Actually, from this historical review, as well as some critiques already made, we will be able to better understand the purpose of this work.

Under this outline, it is necessary to grasp why we need to add Venezuela and Bolivia to the analysis, from now on 'Mercosur+2' or 'Mercosur 6'. SANTOS and SANTOS (2015) discuss the temporary suspension of Paraguay from Mercosur, when "Mercosur announced the decision of its Heads of States, in June 29th, 2012, during its 18th Meeting of the Common Market Council, which took place in the city of Mendoza. Thereupon, Venezuela joined the bloc in a troubled political scenario (SANTOS *et al*., 2016).[25] Not to forget, Venezuela was part of another integration initiative in the region, the Andean Community (AC/CAN)[26] until 2006.

Bolivia, on the other hand, ratified its Mercosur membership in July 2015[27], being even depicted in the official website of Mercosur among its full members. Also, the following piece of information is to be found in the official website:

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[25] 'It gives continuity to the idea that countries need to be democratic in order to be part of this integration, what also justifies the turmoil concerning Venezuela's entrance in Mercosur' (MARIANO and RAMANZINI JR., 2012: 34). The Ushuaia Protocol in 1998 highlights the 'democratic clause', which determines that countries that break the democratic rule shall be suspended from the bloc (SANTOS *et al*., 2017).

[26] Despite its troubled political scenario, the country remains in Mercosur since December 1st, 2016. In accordance with Mercosur's official website, the Bolivarian Republic of Venezuela is suspended from all rights and obligations inherent to its status as a State Party to Mercosur, in accordance with the provisions of the second paragraph of Article 5 of the Ushuaia Protocol. Due to the fact that this is a recent happening and this is the first time it occurs in the bloc, the country remains in the scope of this thesis. See: http://www.mercosur.int/innovaportal/file/2485/1/2006_PROTOCOLO_ES_AdhesionVenezuela.pdf.

[27] In accordance with Mercosur's official website, the Protocol of Bolivia's Accession to Mercosur was already signed by all the States Parties in 2015 and is now being incorporated by the congresses of the States Parties. Despite being already considered a full member, this information is not so accurate throughout the whole website, since it is also found that this country is still on the path of becoming a

> 'The Plurinational State of Bolivia signed the Protocol of Accession to the Common Market of the South (Mercosur) on Friday, July 17 [2015] in Brasilia. (...) The entry of Bolivia reaffirms the consolidation of the process of integration of South America, based on the mutual reinforcement and convergence of the different subregional integration efforts and mechanisms. It also accommodates new trade flows, productive integration and investments. The Plurinational State of Bolivia will gradually adopt the normative acquis of Mercosur, no later than four (4) years from the entry into force of said Protocol.[28]'.

Even briefly, we mention that there are many different integration initiatives in South America. As already mentioned, Venezuela used to be part of CAN and Bolivia is still listed as one of its members. Other projects, as the Initiative for the Integration of the Regional Infrastructure of South America (IIRSA) and the Union of South American Nations (USAN/UNASUR) also address, in a way, the energy issue.[29] Therefore, this issue will still be called upon later on in this thesis.

Table 1 presents a series of socioeconomic indicators for Mercosur and each member country, namely: area (km^2), total population (in million of inhabitants), urban population (% of total population), life expectancy (in years), birth rate (annual average rate/1000 inhabitants), mortality rate (annual average rate/1000 inhabitants), human development index (HDI), Gini index, gross domestic product (GDP) at current prices (billion of dollars), global export f.o.b (million of dollars), global import c.i.f. (million of dollars), and global balance of trade in goods (million of dollars).

member. See: http://www.mercosur.int/innovaportal/file/4054/1/2015_protocolo-adhesion-de-bolivia-al-mcs_es.pdf.

[28] See: http://www.mercosur.int/innovaportal/v/6923/2/innova.front/bolivia-ingresa-al-mercosur.

[29] Not only are there projects from IIRSA in Mercosur, but IIRSA has also become a Technical Forum of USAN recently. The predominant geoeconomic view in the conception of IIRSA should be left aside and (instead it should exist) a geopolitical concept of regional infrastructure integration comprehending: mobility and prioritization of the region's continentality and maritime [potencial], occupation and political, economic and social cohesion of areas and borders, usage of its resources in favor of an automous development of South America (PADULA, 2011).

Table 1. Socioeconomic indicators for Mercosur countries

Countries	Area (km^2)	Population (Millions of people)	Urban Population (%)	Life Expectancy (years)	Birth rate (per 1,000 people)	Death rate (per 1,000 people)	HDI	Gini Index	GDP at Current Prices (US$ bi)	Merchandise Exports f.o.b. (US$ bi)	Merchandise Imports c.i.f. (US$ bi)
Ar	2,800,400	43.8	91.9	76.0	17.36	7.57	0.827	42.7	545.5	57.7	55.6
Bo	1,098,580	10.9	68.9	69.0	23.55	7.35	0.674	45.8	33.8	7.0	8.4
Br	8,515,770	207.7	85.9	75.0	14.41	6.09	0.754	51.3	1,796.2	185.3	143.5
Pa	406,752	6.7	59.9	73.0	21.15	5.69	0.697	48.0	27.4	9.4	9.8
Uy	176,220	3.4	95.5	77.0	14.14	9.35	0.795	41.7	52.4	7.0	8.1
Ve	912,050	31.6	89.0	74.0	19.33	5.57	0.767	44.8	482.4	23.9[30]	13.6
Source (base-year)	WB (2017)	WB (2016)	WB (2016)	WB (2015)	WB (2015)	WB (2015)	UNDP (2015)	WB (2015)[1]	WB (2016)[2]	WB (2016)	WB (2016)

Source: Own elaboration based on WB Statistics and UNDP Data; GDP = gross domestic product; HDI = Human Development Index; f.o.b. = free on board (price of merchandise made available at the place of manufacture or storage); c.i.f. = cost, insurance and freight (price includes merchandise cost and insurance and freight costs); Merchandise imports and exports in current US$; [1] = Ar (2014) and Ve (2006); [2] = Ve (2014).

[30] The value reached US$ 97.4 billion in 2012, when the oil price exceeded US$ 100/barrel.

Table 1 shows that there are many differences between the countries within Mercosur, in terms of area, population and socioeconomic development. Due to these asymmetries, it is necessary to take into account the social dimension when it comes to (energy) policies in the region, because mitigating such asymmetries is one of the main goals of any regional integration process (SANTOS, 2016).

Ergo, based on the historical information and quantitative data presented, it is expected to have clarified the perspective that the thesis assumes when it comes to regional integration. Here, regional integration is *not* political, *neither* economic/commercial, *nor* physical; it is a mix of different perspectives that add up, complement each other, and often overlap. When discussing regional integration, we do not have in mind just exchanges and/or trade flows; in fact, we look at geopolitical, institutional, regulatory, and social issues that are dynamic and therefore transform over time[31].

In this sense, it is important to consider the current Mercosur as a consequence of a long historical process that officially dates from the early 1990s. Although conversations and prior agreements had already taken place in previous decades, Mercosur is indeed born with a strong economic and commercial bias, which partly justifies the insistence on this bilateral relationship (Mercosur-trade) to the present day. Although the social, energy and environmental agenda, for example, has only advanced more particularly from the mid-1990s and 2000s on, it is important to emphasize that there can be no progress of regional integration without political will of governments (SANTOS, 2014a). Thus, regional integration can be understood as a social phenomenon (NUTI, 2006), needing not only the public initiative to make it viable and promote it, but the State itself can create the bases and conditions for the participation of other actors, citizens, non-governmental organizations (NGOs), private agents, among others.

Considering that, it is important to place this debate within the temporal scope of the second half of the decade of 2010. In fact, unlike what has occurred especially since the 1990s, regional integration as a political process does not seem to be a priority for the

[31] At this point, we insist on not using the term ‘to advance’ or ‘to develop’, because both are embedded in a unidirectional, positivistic and hierarchical connotation. Here, as already pointed out, we avoid this kind of approach, even because specialized literature frequently incurs this error. This type of posture almost makes the European Union (EU) the most advanced and therefore appropriate and correct model to be followed in most cases – which is not supported by the recently different conflicts and dilemmas that the EU has been facing, as the pioneering case of Brexit.

region. The shaken relations with Venezuela can confirm this, since for the first time in the history of Mercosur the democratic clause of the Ushuaia Protocol[32] is applied to suspend and withdraw political rights from a state party (SANTOS *et al*., 2017c). In addition, especially with the political changes that occurred in Brazil in 2016, it was evident at different times its interest in making relations in Mercosur more flexible, raising efforts to make feasible the (old-fashioned) bilateral trade project with the European Union (EU). More recently, Argentina's movement of threats to leave Unasur is also noticeable.

It is important to show that although the literature deals with the case almost exclusively from an intra-bloc trade perspective, we concluded that Mercosur has undergone enlargement and deepening processes along almost 30 years of its existance. 'Enlargement' in the sense that it had the accession of new States Parties, such as Venezuela (mid-2012) and Bolivia (in process since 2015), as well as Associated States (Chile, Colombia, Ecuador, Guyana, Suriname and Peru); thus, all the countries of South America are part of Mercosur. 'Deepening' in the sense that although it originally had its focus on trade, the bloc's agenda expanded, touching social, political, environmental and energy issues, for example.

2.3 Energy integration

After analyzing the issues related to regional integration, understanding it as a multifaceted and dynamic process, and focusing on the Mercosur case, this section aims to discuss the particular case of energy integration. Once again, it is important to note that although energy integration is considered a branch of physical integration[33], this thesis understands that energy integration comprises a set of perspectives, being a physical and infrastructure theme, but also a political, institutional, economic, social and environmental one.

[32] See: http://www.mercosur.int/innovaportal/file/4054/1/1998_protocolo_es_ushuaiacomprodemocraticomcs-bych.pdf.

[33] According to the classification of ECLAC (2009). See section 2.2.

OXILIA (2009) claims that there is no precise definition on *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 some activity part of the energy industry through a permanent installation and based on a specific agreement that guides the relationship rules between the parties. However, this conceptual definition does not lead to a great deal of difficulty in coping with this theme, especially if we consider the mutual area of intersection between energy integration and development. This interface makes this concept become even broader.

Also, for LIMA and COUTINHO (2006: 363) 'energy integration and, more widely, infrastructure integration, represents the cornerstone of a new level of regional integration', what is perfectly in line to the central argument of this thesis. In other words, it is defended that (energy) integration allows a series of positive externalities and benefits with multiplier effects to take place in other sectors and in the production chain.

Still concerning the debate on the relevance of studying (energy) integration, FUSER (2011) extends the definition to the goals of energy policies in South America, even defending its tight relationship with the increase of the standard of living of the population. Additionally, DIAS LEITE (2007) defends that *energy and socioeconomic development* walk hand in hand, having reciprocal impacts and, under this approach, it would be impossible not to associate such a debate with countries' joint, long-term national strategies.

In accordance with SANTOS *et al*. (2013) and SANTOS (2014a), the states deal with this sector by taking into account ordinary notions such as *energy planning*, *diversification of energy matrix*, and *energy self-sufficiency*. 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.

As a consequence of the previous section, it was possible to establish that energy integration must be marked and analyzed not only by commercial energy flows, but also by institutional, regulatory and political features. In this way, and as in the concept of energy security, it was identified that there is a lot of resistance to new approaches and methodologies that go beyond the strictly national and state-centric character, by either academics or policymakers[34].

There are several benefits and barriers associated with energy integration. Thus, each of these benefits, which justify the promotion of this modality of integration, is briefly presented and discussed below. Then, the obstacles are presented as well, showing the reason why, despite the associated gains with integration, South America is still at an embryonic stage[35] when it comes to this topic.

2.3.1 Benefits and barriers

The South America region, in contrast to other regions of the world that have already advanced more in this modality of integration, has a relative cultural-linguistic unity, absence of ethnic-religious conflicts, greater agricultural area of the globe, ample supply and diversity of resources natural[36], due to the abundance of water, sun and energy resources (CASTRO *et al*., 2009).

As already shown, energy integration is capable of stimulating effective regional integration, since it has externalities and multiplier effects on other sectors of the economy (ECLAC, 2009, SANTOS, 2014a) and on local industry (PADULA, 2011). In addition, energy integration is able to reduce regional asymmetries, increasing social equity (QUEIROZ and VILELA, 2011).

Due to the nature of investments associated with (physical) energy integration, it has a medium/long term central role in regional development (FUSER, 2011). In addition, it can be argued that since it does not and can not reproduce what has happened in other regions, energy integration allows the integration of the region to be based on a ‘proper view’ of how this process should be carried out (FERRER, 2006).

[34] Therefore, evaluating the history of South American energy integration may mean for many to analyze the failure of energy integration in the region.
[35] The energy exchange is less than 5% of the generation of 2014, of which 93% responds to Paraguay’s exports through its binational dams. There are interconnection infrastructures with very low utilization and difficulties to increase the levels of interchange (CIER, 2016a).
[36] The region has a rich range of energy resources but is unevenly distributed. Ergo, regional energy integration could optimize the use of these resources (CIER, 2017c). It can also be facilitated by the absence of major geopolitical conflicts in the region (RAMOS, 2016).

Given the growing need to consider different actors and institutions in the decision-making process, especially when dealing with regional and/or subcontinental projects, the promotion of energy integration (of Mercosur) needs to incorporate new agents into decisions (SANTOS, 2014a). Among them, we can highlight local governments, the private sector and the populations involved in project areas.

Particularly when it comes to integration and energy in the region, we can highlight the existence of a diversity of multilateral entities that deal with the theme (SANTOS, 2014a, SALOMÃO and DA SILVA, 2008), such as: Latin American Integration Association LAIA/ALADI), the Union of South American Nations (UNASUR) and its South American Energy Council (CES), the Initiative for the Integration of Regional Infrastructure in South America (IIRSA), the Latin American Energy Organization (OLADE)[37], the Regional Energy Integration Commission (CIER), the Economic Commission for Latin America and the Caribbean (ECLAC), the Andean Community of Nations (AC/CAN), and the Common Market of the South (Mercosur) through the Mercosur Structural Convergence Fund (FOCEM). UDAETA *et al*. (2016) also add the role of Regional Association of Oil, Gas and Biofuels Sector Companies in Latin America and Caribbean (ARPEL) and Latin American Integration Association (LAIA).

It is clear that one of the main arguments for the promotion of regional energy integration in any region is to guarantee energy security and increase the reliability of the system (CASTRO *et al*., 2015, MOREIRA and PINTO, 2013). In this sense, the countries involved in the project would be able to deal with common demands and bottlenecks (BERNI, MANDUCA and BAJAY, 2013), based on mutual gains. To do so, they would need to work on a coordinated and cooperative logic (OXILIA, 2009). It would promote economies of scale[38] in the region and stimulate the more efficient allocation of (scarce) resources, creating favorable conditions for the business environment and productive

[37] OLADE defines energy integration as any process or project that involves a long-term installation, interconnection or transaction, either binational or multinational, supported by coordinated national policies, based on a common regulatory framework, focused on a more efficient use of energy resources or infrastructure and aimed at meeting energy requirements regardless of the geographical location of the different centers of supply and demand (OLADE, 2017).

[38] Increasing the scale may allow the monetization of resources that until 10 years ago were not suitable to be used on large scale, like wind and solar energies. In addition, it could provide a better use of renewable energies (CARRASCO, 2017).

investment in the energy sector, as well as encouraging regional joint energy planning (RAMOS, 2016, SANTOS, 2014a, 2014b).

Once again based on economic justification, and linked to the previous one, it is argued that regional energy integration guarantees the joint and more rational use of shared natural resources, existing facilities (CARRASCO, 2017) and investments to be made[39] (BIATO, 2016, CEIA and RIBEIRO, 2016, CASTRO, 2011, LUYO, 2011, CAMPOS *et al*., 2010, QUEIROZ and VILELA, 2010), offering a more efficient service, of higher quality and with lower cost (CIER, 2016b, PADULA, 2011). This argument is particularly important if one considers the importance of sustainable development[40], the fact that the direct consequence of this benefit is the reduction of operating and production costs (ISA, 2016, RAMOS, 2016, WEINTRAUB, 2008), as well as the possible reduction of tariffs[41], precisely relevent when it comes to developing countries, which may affect the demand for this resource.

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 (PAREDES *et al*., 2017, MOURA, 2017, RAMOS, 2016, ZANETTE, 2013, CASTRO *et. al*., 2011, 2012). 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, 2011, SANTOS, 2014a). Among them are the following: the

[39] Equally, the integration in terms of energy equity helps the purpose of savings by allowing to postpone investments in generation, to take advantage of the benefits of hydrological complementarity and resources of the energy matrix, and to reduce operational costs to be able to transfer these savings to the final consumer (CIER, 2016b). Therefore, investing heavily in a sector or seeking inefficient solutions will limit the resources allocated to other areas such as health, education and other communication infrastructures, such as roads, ports, etc. It would be a bad use from the social point of view, a loss of value and would also delay the development (CARRASCO, 2017).

[40] In the VII Latin American and Caribbean Seminar on Energy Efficiency, April 2016, in Montevideo (Uruguay), the Executive Director of CIER, Eng. Juan José Carrasco, highlighted the importance of energy efficiency as a pillar for sustainable development (CIER, 2016a).

[41]The most affordable price of energy allows a better level of international competitiveness and insertion of the countries of the region (MAYA, 2015).

Inter-American Development Bank (IADB), the World Bank (WB) and its International Finance Corporation (IFC), the Venezuela Economic and Social Development Bank (BANDES), the Brazilian Development Bank (BNDES), the Development Bank of Latin America/ Andean Development Corporation (CAF), the Economic Commission for Latin America and the Caribbean (ECLAC), the Financial Fund for the Development of the Río de Plata Basin (FONPLATA), Common Market of the South (Mercosur), through FOCEM, and Latin American Energy Organization (OLADE)[42].

It is important to consider that energy integration, as joint regional planning by states, can (and should) prioritize renewable sources, including the incorporation of Non-Conventional Renewable Energy (NCRE)[43]. This is especially possible and feasible in Mercosur countries, given the profile of their energy matrix, therefore energy integration in these terms can contribute to reduce CO_2 emissions and fight against climate change (CIER, 2016b, RAMOS, 2016).

Often in the literature, it is stressed the importance of Brazil[44] 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)[45] (BIATO *et al*., 2016).

This integration of Brazilian submarkets allowed savings of around 20% of investments (MOREIRA and PINTO, 2013). Likewise, it should be mentioned that Brazil also has

[42] More recently, it is worth noting the Chinese project known as 'One Belt, One Road', as well as the country's closer ties with countries in the region, such as Chile and Bolivia, through the Asian Infrastructure Investment Bank (AIIB). See: https://www.telesurtv.net/english/news/Asia-and-Latin-America-Strenthen-Economic-Ties-20170513-0003.html.

[43] They have less social and environmental impact, such as the generation of energy from biomass, SHPs, wind, solar, tidal energy, geothermal. The following are some examples of NCRE projects: biomass cogeneration plants, plants organic waste, wind farms, small hydro passing, solar plants.

[44] For many authors, Brazil would be the 'natural candidate' for regional leadership (MALAMUD and SCHMITTER, 2011). It is worth mentioning that the country in fact tried to break the inertia of the regional integration agenda with the launch of the Union of South American Nations (UNASUR) in 2008.

[45] In addition to its privileged geographic location in the South American subcontinent, the Brazilian Electric System (BES/SEB) presents a consistent and dynamic model, with very solid institutional and economic bases and an efficient financing pattern (CASTRO, 2010). It is worth mentioning that SIN is the largest interconnected transmission system in the world.

some interconnections with the neighboring countries' electricity system (MOURA *et al*., 2012), which will be better presented and discussed in **Chapter 3**.

Notwithstanding, QUEIROZ *et al*. (2013) emphasize that the regional predominance in terms of strategic resources and political power leads to a questioning and distrust of its neighbors when it comes to Brazil's potential hegemony in the subcontinent. Ergo, they argue that, on the one hand, there was a greater political interest during Lula's governments (2003-2010) on the Union of South American Nations (UNASUR), the Initiative for the Integration of Regional Infrastructure in South America (IIRSA) and the investments of the Brazilian Development Bank (BNDES) and Bank of Brazil (BB) in the sector. On the other hand, this led to an increasing fear concerning Brazil's power in the region[46], what jeopardizes Mercosur's own progress (BIATO, CASTRO and ROSENTAL, 2016), since it brings to the surface the fear of other countries that would have to operate under the aegis of a regional sub-imperialist Brazilian logic.

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 (BAER, CAVALCANTI and SILVA, 2002, CARRANZA, 2003, BIATO, 2016, SANTOS, 2014a). 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, CASTRO and ROSENTAL, 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.

[46] With the great participation of Brazilian banks, companies and contractors in these projects, there are inevitably questions about the (real) intentions and Brazilian objectives with these integration projects. The term 'regional sub-imperialism' (MARINI, 2012) and/or 'bandeirantes de la XXI century' (BIATO, 2016) is often found in the literature on regional integration, especially among non-Brazilian Latin researchers.

In general, there are institutional and regulatory asymmetries that make the implementation of energy integration projects in the region too complex and costly (CASTRO, 2009, CEIA and RIBEIRO, 2016, QUEIROZ *et al*., 2013). This complexity and diversity should be reduced in order to minimize economic uncertainties, legal insecurities and political risks (FUSER, 2011, SOLOMÃO and DA SILVA, 2008).

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, 2014a, VÉLEZ, 2005). 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 this sense, these authors present some cases that clearly show the risk associated with this obstacle: (i) the change in gas sales in Bolivia, in 2006; (ii) the interruption of Argentina's 2,000 MW supply, in 2007; (iii) the renegotiation of the Itaipu agreement, requested by Paraguay; (iv) the rationing of energy in Venezuela, with consequences for the supply of energy in Roraima; and (v) the drastic reduction in the supply of Argentine natural gas to Chile.

The harmonization of these regulatory asymmetries has been fundamental since the earliest stages of energy integration, when it seeked to establish common and clear trading rules for participating countries in order to promote the energy sector's own dynamics (MOREIRA and PINTO, 2013, ZANETTE, 2013).

Related to that obstacle, the fear of loss of national sovereignty and political distrust are at the root of any regional integration initiatives, particularly those that touch on sensitive issues such as infrastructure and legal, regulatory and regulatory arrangements (BIATO, 2016). Specifically concerning the issue of energy, this fear is evident in national energy plans, in which terms such as *energy self-sufficiency* and *national energy sovereignty* and *energy security* are the priorities of every country (SANTOS, 2014a, 2014b). 'The major obstacle to the development of new supplies is not geology but what happens above ground: namely, international affairs, politics, decision-making by governments (...)' (YERGIN, 2006: 74).

Thus, in a similar way to what happened in Europe, it is necessary to create common political foundations to facilitate and encourage regional energy integration. Therefore, as electricity is a fundamental input for production of goods and services, in addition to guaranteeing the social well-being of families, trust based on consistent political arrangements can give the guarantees that countries need (CASTRO, 2016).

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[47]. 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, 2014a, 2014b). Despite this hurdle, RAMOS (2016) argues that regional planning should contemplate and respect the autonomy of the energy policies of each country, so it suggests the establishment of a flexible commercial scheme.[48].

Although in South America there is the hydroelectric plant of Salto Grande on the Uruguay River (Ar-Uy), Itaipu on the Paraná River (Br-Py) and Yacyretá on the Paraná River (Ar-Py) as an example of large dams (SANTOS and SANTOS, 2016, QUEIROZ and VILELA, 2010, UDAEDA *et al*., 2006), it should be noted that the strong binational profile of most of the bolder projects concerning regional energy integration can be considered as an obstacle to effective regional/multilateral energy integration (BERTINAT and ARELOVICH, 2012, BIATO, 2016, MOREIRA and PINTO, 2013, SANTOS, 2014b, SENNES and PEDROTTI, 2008), but it can also be assumed as an intermediary step for this. Most of the time, these projects are born through international bilateral treaties, which are difficult to be legitimized (RAMOS, 2016).

Although the existence of different sources of financing can be considered as a facilitator for regional energy integration, the cost of such loans may actually make the financing issue a barrier (ARELOVICH, 2012, CARRASCO, 2017). It is worth mentioning that

[47] 'In South America, infrastructure constructions interconnecting the network industries of different countries were historically based on bilateral (binational) commitments. Thus, bilateral commitments can be considered as the basis of the institutional framework of the construction of infrastructures existing in South America.' (HALLACK, 2014: 354).

[48] Ergo, it is necessary to evaluate the existing trade-off between prioritization of regional planning vs. national one, as they may shock or even be incompatible.

ventures in the energy sector often require large initial investments, which only have medium/long term returns (long payback).

However, since they are developing countries, they tend to have higher country risk, which means that interest rates on loans are higher. Thus, in order to deepen South American energy integration, it is necessary to face project financing, which should have lower interest rates, longer paybacks, and more flexible conditionalities (SANTOS, 2014a).

Information and technological issues can also constitute barriers and obstacles to full regional energy integration. Information on net future demand forecast, futures markets and price estimates are basic and necessary prerequisites for national markets to be included in a regional one (ZANETTE, 2013). Different technologies can also pose difficulties when (i) there are differences between countries that generate, transmit and distribute electricity at different frequencies (50Hz or 60Hz in South America); (ii) several countries have borders on the Andes or the Amazon Rainforest, being separated from their neighbors by geographical obstacles and/or demographic voids with a large territorial extension; and (iii) coincidentally in the Mercosur countries, the exchange (imports or exports) of energy with Brazilian market depends on frequency conversion.

Climatic adversities can particularly affect the hydrological regime, changing the pluviometric regime and consequently damaging the generation of energy in the turbines of the hydroelectric plants (CASTRO, 2010, 2011). Therefore, meteorological uncertainty especially affects countries whose share of hydroelectric production is significant (LANDAU, 2008a, 2008b) – as is the case of Brazil, Colombia and Paraguay. The Brazilian blackout (power outage) of 2001 is an exemplary case of how poor resource management and the lack of internal interconnection to promote supply in scarce areas pose a real risk to the security of energy supply. In this way, regional energy integration represents an alternative to energy security, since it increases the reliability and quality of the system, reducing emergency risks and blackouts (CIER, 2016b).

The environmental issue is considered by many to be an obstacle to the advancement of regional energy projects, either because they make the creation of certain hydropower plants more expensive or even impossible. However, it is important to consider that South America has the Amazon region, the current exploitation center for hydroelectric potential. At the same time, in addition to the environmental issue itself, there is a social issue associated with it in the region, since there are several riverine, indigenous and local populations that are directly or indirectly affected by such projects. In this sense,

> 'Serious damages caused by the implementation of power plants on traditional populations of the Brazilian Amazon (Tucuruí, Balbina), Chile (Bio Bio) and Colombia (Arru) are equally known. Binational projects did not escape the same problem, such as the problems seen in Yaciretá and even in Itaipu where the situation of Guarani Oco'y remains unresolved.' (VAINER and NUTI, 2008 *apud* CEIA and RIBEIRO, 2016: 145)

Briefly, ISA (2016) points out that the key factors for regional energy integration can be framed in the 5Rs methodology[49]. (i) Resources: to take advantage of available complementarities (hydrology, demand, etc.); (ii) Rules: to make agreements and basic harmonization of regulatory and regulatory frameworks; (iii) Networks: to develop transmission infrastructure in a coordinated manner with national planning; (iv) Support from governments: to ensure will and commitment, backed by policies and agreements; and (v) Regional vision: to deepen processes of cooperation and energy integration in the region. It is also emphasized that self-supply does not necessarily aim at optimization, and should not lead to the protection of energy resources, what is completely in line with thesis argument.

Recently, changes in the electric scenario have added challenges to the energy integration of the countries, constituting great challenges even for modeling, such as '(i) the growing and large scale participation of renewable sources, especially the intermittent ones; (ii) contingency of the power source due to environmental restrictions; (iii) the strong presence of distributed generation; and (iv) the advancement of Smart Grids in distribution systems.' (RAMOS, 2016: 73-74). Also noteworthy is the difficulty to consider the storage of energy, such as batteries[50], which leads to the need to consider new technical, commercial and regulatory aspects that must be taken into account, affecting the business model and the tariff structure (CIER, 2016b). Indeed, the increment

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[49] It makes sense only in Portuguese or Spanish, as resources, rules, networks, government support and regional vision mean *Regras* (*reglas*), *Redes*, *Respaldo dos governos* (*respaldo de los gobiernos*) and *visão Regional* (*visión regional*).

[50] For users, they guarantee for example the increase in reliability, the increase in the quality of energy, the reduction of the number of interruptions, the efficient use of energy, the lower cost of energy, the use of renewable energies, and the decrease of polluting emissions. For distributors, for instance, they allow the reduction of losses, free system capacity and decrease in investment (CIER, 2016b).

of new renewable sources (such as wind, solar and biomass) and the introduction of new non-renewable sources (such as shale gas and LNG), as well as new configurations by the demand side (energy efficiency, electric vehicle, smart grid and distributed generation) are challenges to integrated regional energy planning.

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.

These obstacles are reflected in the loss of energy and dynamism of the forums responsible for the regional (energy) integration agenda, in particular in the Common Market of the South (Mercosur) and in the Union of South American Nations (UNASUR). Without political will, the project has no support and strength to overcome national demands of each country (RAMOS, 2016, SANTOS, 2014a). On the other hand, when there is political will, the regulatory frameworks will be adjusted to guarantee the most economic and safe operation of the systems (CIER, 2016b).

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 for Brazil, in the case of Itaipu) created a bad and pessimistic history for the advancement of the process. In addition, the relative abundance of energy resources of the countries of the region does not push for integration, leading to (i) sub-optimal exploitation of these resources; (ii) overestimation of the need for investments; and (iii) underutilization of existing facilities and opportunities.

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 the 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.

2.3.2 Market integration modalities

The main purpose of this subsection is to present the different modalities of market integration, in order to find out which would be ideal in the case of the Mercosur countries and South America in general. In this way, and without intending to make a deep institutionalist analysis of theories of regional integration, it will be seen that different modalities pass between two extremes, which can be identified with the intergovernmentalist model and the neo-functionalist model.

Before evaluating each case, it is important to establish what is meant by institutions in this work. By institutions it is understood a normative set oriented to certain objectives, as well as the instruments that guarantee its execution, in order to direct the individual behavior in a certain direction (KEGEL and AMAL, 2012). In this sense, they would constitute the restrictions created by the societies themselves, which define the limits where exchanges and individual choices occur, establishing rights, prohibitions and sanctions provided by law and social conventions.

Ergo, institutions reduce uncertainties, stimulate cooperation and improve economic coordination; at the international level, create an environment of greater predictability and security in international relations and thus overcome problems of cooperation between States. In both cases, they generate greater confidence over information and align mutual expectations of agents (SANTOS, 2014a).

In a simplified way, the institutional framework based on the neofunctional model has a strong supranational character, that is, there is a transfer of power from the countries involved to a higher level. This is the case of some European Union (EU) institutions, which restrict and impose targets, policies and rules on countries participating in the regional bloc. On the other hand, the intergovernmental model has strong autonomy and independence of the parties involved, so there is no assignment of sovereignty in favor of a supranational body responsible for a top-down decision making. This case is closer to the institutions part of Latin American integration models, where states, due to a colonial and more recently dictatorial past, resist relinquishing national sovereignty to supranational decision-makers.

Although there may be different possibilities for institutional arrangements in energy and various aspects that determine the integration model (legal, political, commercial, technical, institutional, geographical, etc.), as it has already been said, the integration depends above all on political will. Therefore, it requires the acceptance of commitments where regional gains prevail over national interests, thus overcoming the tension between integration and sovereignty.

Since the second half of the 20th century, mainly since the late 1960s, joint projects have been developed in the energy area, the oldest being the Itaipu Binacional and the energy interconnection of Acaray, both projects carried out between Brazil and Paraguay. At the same time, in the early 1970s, other projects were conducted, such as the construction of the Yacyretá Binational Plant, involving Argentina and Uruguay.

From a historical point of view, the evolution of the energy markets of the region took place as follows: (i) 1980s: the first integration works are consolidated, initiating the relationship between agents from different countries. Basically of binational character, the State corresponded to the exclusive responsible for the development of the sector, assuming that the electric industry was a natural monopoly; (ii) 1990s: with the macroeconomic and regulatory reforms, emphasis is placed on the economic efficiency of the enterprises. Ergo, there is a request for new investments, as well as private participation in them; and (iii) 2000s: the decade represents a significant shift in the orientation of some countries. Consequently, there is less openness in the energy sector, changes in certain regulatory guidelines and inclusion of subsidies. The need to ensure security of supply as well as to reduce energy dependency is emphasized.

Thanks to the changing profile of the integration of energy markets, there is confusion about the concepts of energy integration and cooperation, which makes these terms used as synonyms in the literature[51]. In this thesis, energy cooperation corresponds to an

[51] Such confusion is not limited to the energy issue, but is particularly frequent in the economic and physical approaches to integration.

(intermediate) stage of the regional (energy) integration process, according to the model theorized by ISA as indicated in the figure below.

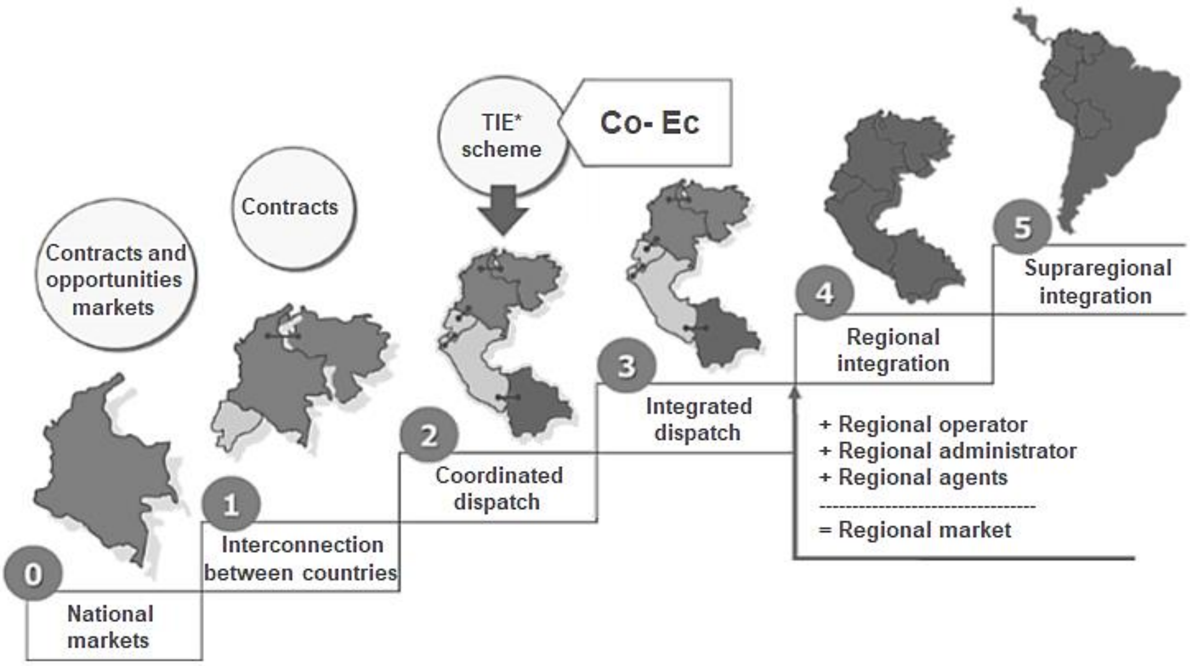

Figure 2. Expected evolution of energy markets integration

Source: Adapted from ISA (2007); * TIE = International Energy Transactions.

Based on **Figure 2**, it is noted that the first four moments of the regional energy integration process formulated (steps 0 to 3) deal with national markets that progressively build physical interconnections between countries, and then, by the coordinated dispatch and then integrated dispatch among them. So far, there have been distinct forms of energy cooperation between countries; however, the next stage, that of 'regional integration' (step 4), which is marked by the presence of regional operator, regional administrator and regional agents, is shaped by the existence of a regional market.

According to RUIZ-CARO (2006, 2010), it is possible to identify three types of (economic) benefits in electric interconnection enterprises, namely: (i) Construction of binational hydroelectric plants: they started operating around 1980 and were built by state companies (whose costs and investments were recovered through the remuneration of the energy generated by the plants); (ii) Firm energy sales: assures the company that sells a flow of resources to cover the costs and financing of interconnection works; to the company that buys, it assures the guarantee of supply of its demand; and (iii) Opportunity exchange: takes advantage of marginal cost differences between interconnected systems, without excluding the possibility of (longer term) contracts.

According to BIATO *et al*. (2016), there are three main modalities of energy integration in the region. The first group incorporates binational hydroelectric dams, being less advanced. The second group is intermediate and "only involves power purchase and sale agreements on the spot market. It does not establish synergies capable of levering more ambitious projects or initiatives, thus being limited to meet emergency needs and demands with flexibility" (*Ibid*.: 65). The third group does not involve joint ventures, but aim to export/import electricity through medium and long-term contracts.

Figure 3 below shows the evolution of energy markets integration suggested by Altieri (2015). The further to the right, the more advanced is the process of integration of the energy systems of the region.

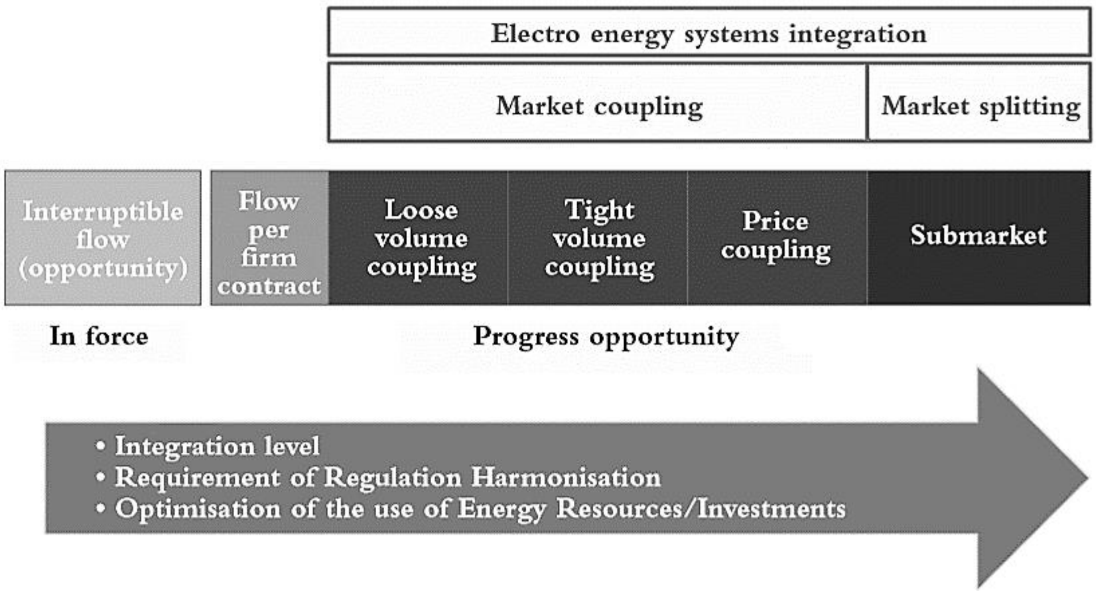

Figure 3. Evolution of energy markets integration

Source: ALTIERI (2015)

RAMOS (2016) points out that there are two modalities of market integration: (i) construction of binational plants; and (ii) electric interconnection between markets. The first is the most used in the region, when two countries build a (border) plant for strategic, geopolitical and/or economic reasons. This is the case of Itaipu (Br-Py, 14 GW), Salto Grande (Ar-Uy, 1,9 GW) and Yacyretá (Ay-Py, 3,1 GW)[52], in which the country with the largest consumer market often leverages the project and, most of the time, fulfills the role of economic viabilizer of the enterprise, guaranteeing its financing.[53]

These examples refer to 'conventional' binational dams, but there may also be joint uses located entirely within a single country ('non-conventional' binational dams). This is the case of ventures such as in Bolivia (Rio Madeira and Cachuela Esperanza) and Peru (Inambari), since both countries lack scale in order to enable explotation and the economic feasibility of the respective projects. However, as shown, the integration through the construction of binational power plants can be assumed as an obstacle to the effective integration of regional electric markets.

In turn, the electric interconnection between markets has more long-term character and can be divided into four types. Despite its particularities, advantages and drawbacks, all seek the same end, which is to allocate scarce cross border grid capacity in the most efficient way (ONDŘICH, 2014).

Opportunity Interchange (interruptible flow) is the first stage, when the volume and price offer is interruptible, usually 'for a determined period with very specific conditions related to the source to be provided and pre-established commercial conditions.' (RAMOS, 2016: 81). It is then an exceptional and conjunctural energy exchange, thus vulnerable to the momentary interests of countries involved. In every energy exchange, economic and regulatory negotiations need to be (re)evaluated, what reduces the dynamism of the negotiations, without substantially and structurally affecting the energy balance of the countries involved.

The second stage of the electrical interconnection of markets is Firm Energy Contracting (flow per firm contract), when the parties involved define bilateral contracts. 'In Brazil, contracting could be made in the Free Hiring Environment (ACL) or the Regulated Hiring Environment (ACR). In ACR the transaction would be mandatorily made through

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[52] The presentation of binational plants and international energy interconnections in South America will be made in **Chapter 3**. **Appendix B** presents the Central American international interconnections, as well as the Central American Electrical Interconnection System (SIEPAC).

[53] The country that provides the financing often receives reimbursement in the form of energy (or abatement of the cost of the fee paid).

centralised auctions aiming to serve Utility Companies.' (*Ibid.*: 94). Auctions can happen either for new energy (longer periods) or existing energy (shorter periods).

In this case, there is influence on the price by the Short-Term Market (MCP) of each country due to this amount of firm energy. In this way, it is up to each country to define the price in the MCP and how to incorporate this amount into consideration. In addition, there is more exposure and vulnerability on the exporter side, since much of the trade rules (structure and regulation negotiation) is defined by the importer country, and it is subject to possible penalties.

Unlike the previous case, Firm Energy Contracting already requires greater coordination between the energy planning of the countries involved during the contract period, despite the autonomy they still have.

Advancing in the market integration modalities, Market Coupling represents the third stage of the electric interconnection of markets. 'Market coupling is defined as the use of implicit auctioning involving two or more power exchanges (PXs).' (BAUMANN, 2014: 30). It is possible to affirm that some of its advantages are in being economically efficient, and also provide regional incentives. Some of its drawbacks is the absence of incentive for Transmission System Operator (TSO) to expand capacity (VAN BLIJSWIJK and DE VRIES, 2011).

Besides, 'the countries involved (…) shall demand at least a minimum regulatory harmonisation when considering the energy volumes and short-term price formation of each country, as well as volumes offered and demanded, and energy planning.' (RAMOS, 2016: 82). It is important to stress that with not enough interconnections, 'there will not be a single price between the coupled countries. (...) Prices between countries will differ for as long as bottlenecks in the transmission systems and in particular on interconnectors remain, even after market coupling.' (ONDŘICH, 2014).

There are three different kinds of coupling markets, the first two ones are volume-related and the last one is price-related. Volume coupling can be defined as a 'coordinated day-ahead auction involving two or more power markets [where] cross-border volumes computed by an Auction Office are transferred to the power exchanges, which consider them as price inelastic bids into their local system.' (ENTSO-E, 2010: 2). This form of implicit allocation has a 'more humble' objective than price coupling (JANSSEN *et al.*, 2012), allowing the coupled markets to stay more independent while being coupled (GLACHANT, 2010).

The first kind of volume coupling is the Loose Volume Coupling. In this case, 'the volume traded between two countries or regions is calculated in a first step and then prices are calculated separately in a second step.' (BAUMANN, 2014: 31).

> 'Each country defines its curve relating the Marginal Cost of Operation (CMO) and interchange (export or import curve) with price and quantity offers. A single and common algorithm between countries crosses export and import offers and sets the interchange flow. Thus, each country shall be entitled to internalise the results of this singly algorithm in the short-term market pricing, as well as commercial and regulatory discounts in its models.' (RAMOS, 2016: 95).

As one can imagine, in order to carry out coordinated studies, it is necessary that countries have free access to the electromagnetic data of all others involved. Therefore, each country must act in a non-discriminatory way between the companies that make up the coupling so that the relationship can be reliable and lasting[54].

The second kind of coupling markets is the Tight Volume Coupling.

> '[It] implies a coordinated dispatch among countries, and the interchange is defined through a single computational model based on simplified systems information. Each operator internalises the interchange flow in its model and sets prices for the short-term market in this approach. Transactions occur in each country's short-term market and, obviously, respect the commercial rules of the country in which the amount is being settled. This allows national energy policies to remain autonomous.' (RAMOS, 2016: 83).

'The term "tight" means in this context that the traded volume is calculated based on all relevant information such as the amount of cross border capacity, order books of all energy exchanges and TSOs in the coupled area.' (TENNET, 2013 *apud* BAUMANN, 2014: 31). This is the main difference compared to Loose Volume Coupling, because now the calculation is performed using all relevant information. 'In case of a structural

[54] 'Methodologies to define import and export curves should be transparent and reproducible.' (RAMOS, 2016: 83).

balance, the short-term interchange can even overcome the volume of the amount hired generating differences that would be settled in the short-term market.' (RAMOS, 2016: 83)[55].

Last, but not least, there is also the Price Coupling as the third kind of coupling markets, which is used the most. Price coupling was first introduced in 2006 between France, Belgium and the Netherlands, known as Trilateral Market Coupling (TMC), having the advantage of avoiding price[56] or flow discrepancies like exports from a high price zone to a low price zone or price differences in case of no congestion (ENTSO-E, 2010, GLACHANT, 2010, TENNET, 2013, WEBER *et al*., , 2010).

> 'Price coupling requires a single computational model to calculate the Marginal Cost of Operation (CMO) of member countries and interchange flow occurs based on detailed information of countries' electrical energy systems. National operators internalise interchange flows established by the model and calculate short-term prices with the same computational model. So that this mode works, the coordination level should be extremely high and countries lose autonomy in their policies, thus requiring an Integrated Energy Planning comprising not only electricity but generation sources that shall be used and how this is related to other energy markets, such as the gas market.' (RAMOS, 2016: 83).

The most advanced example of this model is Central West Europe (CWE), involving the operators of France, Germany, Belgium, The Netherlands and Luxembourg, and the electricity exchange EPEX-SPOT.

Finally, the fourth and final stage of the electric market interconnection (market integration) is Market Splitting, corresponding to full market integration. Among its advantages we have it being economically efficient, having increased liquidity, and providing locational incentives. Among its drawbacks, we have the fact that there is no

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[55] A successful example of this approach is Nordpool's coupling with CWE, includying Belgium, France, Germany, Luxembourg and the Netherlands.

[56] 'A single price is not and should not be the only or even the best criterion according to which progress towards achieving a well-functioning single market is judged. There can be, for example, situations in which prices between the two or more countries are very similar due to abuse of dominant market power of a dominant market participant in one or more countries' (ONDŘICH, 2014).

incentive for Transmission System Operator (TSO) to expand capacity (VAN BLIJSWIJK and DE VRIES, 2011).

> 'it would only count on one operator for countries of the bloc being integrated, and each country or region would be treated as a submarket similar to what Brazil conducts internally in the National Interconnected System (SIN) operation. For example, it would be as if the SIN operation model was replicated on a larger scale, encompassing all countries that wish to be integrated where each country represents a submarket or zone. There would be a single algorithm to define the dispatch and to form the CMO and the short-term market price. Given this integrated operation, almost full harmonisation in countries' regulation, generation and transmission expansion criteria and commercial assets remuneration rules is necessary.' (RAMOS, 2016: 84).

There are different definitions to Market Splitting and they basically rely on different usage of terms. 'In Scandinavia market splitting is used as an expression for a method where a single market is "split" in case of congestion. In continental Europe, (…) often means the coordinated use of power exchanges where different neighboring markets are operated separately before congestion.' (BAUMANN, 2014: 29).

Although it seems unlikely to happen in the South American subcontinent, the most controversial point would be the definition of a single operator, which implies a loss of countries' autonomy and the fear that this operator acts in a discriminatory manner benefiting countries with the largest consumer market. Generally, the two most advanced examples are MIBEL (Portugal and Spain) and Nordpool (Norway, Sweden, Finland and Denmark).

Figure 4 presents a summary table of the different market integration models (interruptible flow, flow per contracy, loose/tight volume coupling, price coupling, and market splitting) in terms of its operation, interchange, short-term market (MCP) price, contract, ballast, MCP, commercialization rules, energy planning, and show international experiences as examples of each modality. Here, the aim is to consolidate the concepts and allow the comparison between them in an objective and simplified way.

			Market coupling		Market Splitting
Model	Interruptible flow (opportunity)	Flow per contract	Volume coupling	Price coupling	Market splitting (submarket)
Operation	Coordinated (one or more operators)				Integrated (single operator)
Interchange	Agreed by countries	Defined by contract	Defined by separated models	Defined by the single model	Defined by the single model
MCP Price	No	Calculated by country	Calculated by country internalising the interchange defined in a coordinated manner	Determined by the same model that determines the interchange	Defined by the single model
Contract	Interruptible	Firm			
Ballast	No	Yes			
MCP	Net energy in MCP	Accounts contract on border and calculates ballast	Yes (structural balance needs to be ensured and the transmission capacity needs to be proper)		
Commercialisation rules	Agreed		Similar		Equal
Energy Planning	No		Coordinated		Integrated
International experience	Central America (MER)	LP contracting in Europe	Nordpool + CWE	CWE	Nordpool

Figure 4. Summary of Markets Integration Modalities[57]

Source: Adapted from RAMOS (2016); MCP = short-term market; MER = (Central American) Regional Electricity Market; LP = long run; CWE = Central West Europe.

In the Fourth Ibero-American Seminar on Renewable Energies (SIBER IV), Rafael Ferreira, Advisor to the Presidency of the (Brazilian) Energy Research Company (EPE), said that this future harmonization must take into account the sovereignty of each country, identify the interface points, generate an adequate framework for investments, design a cost structure that does not generate distortions in the short term and create mechanisms

[57] To check more European market coupling initiatives, see **Appendix A**.

so that countries that are transit (which are not buyers or sellers), accept interconnection until the Market integration (CIER, 2017a).

Ergo, it is necessary to show integration paths by sequential stages. Starting by proposing alternatives for energy exchanges in both current interconnections and new generation/transmission projects that allow progress in the integration process would be an important first step. Then, go through optimization and opportunity exchanges, long-term contracting of firm energies, coupling of markets until full market integration would correspond to expected steps.

Notwithstanding, the region still does not have a common vision and long-term strategy on energy integration. Each country seeks its energy self-sufficiency and secondly seeks to sell surpluses to amortize its over-investments. These strategies have shown that they are not safer, they are more expensive and, in turn, do not allow the development of unconventional renewable energies to their full potential.

Considering the current regulatory frameworks of the Southern Cone countries, RAMOS (2016) suggests: (i) Direct bilateral contracting, which in the Brazilian case could be both in the Free Hiring Environment (ACL) and in Regulated Hiring Environment (ACR)[58]; (ii) Interchange defined by the buyer and limited to the contracted value; (iii) Pricing and trade rules should be defined in/by each country; (iv) Non-delivery of energy hired implies purchase at MCP and payment of penalties; and (v) Energy Planning should include partial coordination in order to safeguard an important level of independence for countries signatory of agreements/treaties for energy integration[59].

> 'Short, medium and long-term integration modes should be defined considering specific planning, operation and trade aspects for each interchange modality, making progress in the construction of a plan for the implementation of the necessary projects (Plants, Transmission Lines and Substations), also preparing legal and commercial frameworks that allow for the integration with consistent and attractive basis for Agents, including international treaties among the countries involved for the sake of legal security also supporting the financial and

[58] In the latter case through new and/or existing energy auction.

[59] 'If Brazil is the importer, the volume hired represents generation and may ballast sales and, on the other hand, generation charges must be paid. If Brazil is the exporter, export should be represented as load and shall present contractual coverage with the payment of consumption charges.' (RAMOS, 2016: 87).

operational safety of transactions to be conducted in the markets of each Country involved.' (*Ibid*.: 88-89).

Thus, the author flexes his commercial vision of regional energy integration, highlighting the need for diverse planning through short, medium and long-term perspectives. In addition, it is worth noting that no matter the deadline, different agreements must consider the procedures and referrals applicable to exceptional cases, such as shortages and/or energy crisis situations.

Thus, many consider that building an integrated energy market like the European one in the South American region is unlikely to happen due to the different barriers already presented (see subsection 2.3.1). This is aggravated, because the commercial model of Brazil, the largest regional energy market, (i) is for physical guarantee of purchase/sale, not for energy; and (ii) the physical guarantee can only be calculated in a modeled system as being 'closed in itself'. In this way, the characteristics of the Brazilian market grounded in the concept of 'ballast' (physical guarantee) make integration similar to the European model impossible to happen[60]. This ratifies section 2.2, which states that the models of integration are particular and should not mimic the European one, taken as right and ideal, therefore corresponding to what must be followed.

Given these limitations related to the architecture of the Brazilian commercial model, the country should play an incremental role, granting a regulatory environment in which neighboring countries that want to buy/sell electricity from the Brazilian market do so with free access and clear and non-discriminatory rules[61].

Consequently, RAMOS (2016) suggests that Brazil incorporate a list of recommendations in order to create a favourable marketplace for regional integration: (i) Clear regulatory mechanisms[62] for energy import and export, considering the particularity of the cases; (ii) Allow the participation of importers in electricity auctions; (iii) Encourage the construction of projects aimed at exporting[63]; (iv) Financial guarantees and commercial

[60] 'Europe is the most advanced continent in this sense, having examples of integration by coupling methodology (volume and price) and examples of full integration, which is also known as market splitting.' (RAMOS, 2016: 93).

[61] Such was the case between Colombia and Ecuador.

[62] Even by the existence of possible barriers due to the nature of the operation of the Brazilian institutional model, such as thermal dispatch out of the merit order and resulting charges, what artificially affect prices in the short-term market and impact costs of several agents.

[63] There are many power plants construction opportunities in the Amazon, as well as wind and thermal projects in the Southern Cone region.

aspects as exchange rate and risk-taking; and (v) Specific allotments of the trade rules system that can derail a commercial interchange process by adding costs affecting the economic feasibility of the energy interchanged. However, the exclusively commercial focus of the suggestions made by the author is clear, and it is a limitation from the point of view of guaranteeing the goal.

> ‘Brazil’s integration with other Southern Cone markets with which it has borders should be established as “Loose Volume Coupling” where each country [has its Operator and] calculates its Marginal Cost of Operation independently and is free to continuously set purchase and sale prices by adding the margin it deems appropriate in relation to the pure marginal cost in electricity connection point(s) (addition of congestion costs, for example).’ (RAMOS, 2016: 93-94).

Again, it is perceived that the author’s proposal has limitations. Undoubtedly, this is due to the influence of conjunctural factors and the current scenario of regional energy integration (since the current context of Mercosur is characterized by dispatch based on contracts). Ergo, there is no optimization between systems. Without a single operator, the exploitation and management of the region’s natural resources will not be optimized and therefore the subject will continue to be treated in the light of trade flows, either from bilateral agreements or from the international energy interconnections region.

However, as discussed in section 2.2, care and caution are required when interpreting these models in stages, which suggest the normative idea that institutionalization is necessarily positive per se. The existence of these new rules and actors do not necessarily guarantee the optimization of regional energy planning, since political will and respect for the rules are fundamental requirements.

Although this caveat is taken into account, the central argument of this thesis is that, with regard to the issue of South American energy integration, the creation and development of these institutions would benefit the process. Certainly, like any other model, there are simplifications and normative abstractions (the process does not necessarily have to go through all the stages presented, which are not dated in time). The purpose of these schemes is to present the movement expected to be achieved when there is a regional intention to develop a model of energy integration, demonstrating the degree of political and institutional consolidation of the steps themselves.

In general words, regarding market integration modalities, it was perceived that current energy intergration in Mercosur is based on the spot market and (bilateral) contracts. Thus, there is no effective joint regional planning, nor optimization between systems, but only opportunities exchanges[64]. Although regional market splitting is desired, it is important to consider that as long as there is not something really regional, it is necessary that the countries at least take into account the plans of their neighbors when preparing their energy expansion and operation plans. Undoubtedly, this will be a first step towards a path of regional energy planning.

In general, the purpose of this chapter was to present and discuss the three main concepts of the thesis. In proposing a related discussion between energy security and regional integration, analyzing South American energy integration, it was emphasized that regional energy integration is capable of promoting regional energy security. Thus, the level of analysis were changed, surpassing the national one and proposing a regional dimension.

After reviewing the different interpretations of the concepts discussed in the chapter, our objective was not to establish a single definition based on the contribution of the different disciplines that discuss each of these concepts. In fact, the idea was to present the diversity of approaches and interpretations and, in the end, to show that our understanding of the concept considers its multidisciplinarity feature. In this way, we consider the environmental, social and institutional variables (politcs, culture, rules, i.e.) in a regional dimension.

[64] Cases like Itaipu, with stable and predictable long-term supply mechanisms are, unfortunately, an exception in the region.

3. National perspectives

The main purpose of this chapter is to introduce the energy scenario in the Mercosur countries. The base-year of following analysis is 2015 in order to standardize the data depicted in upcoming tables and figures; thus, the methodology used to carry out a comparative data analysis for the different countries is guaranteed. The national quantitative primary sources are databases such as World Databank, sieLAC, ECLACstat, CIER, COCIER, national energy ministries, British Petroleum (BP), World Energy Council (WEC). In addition, the use of national and regional qualitative primary sources such as norms, laws, international treaties, agreements, memorandum of understanding, regulatory frameworks, programs and planning are emphasized.

The chapter will be divided as follows: first, a comparative analysis of different primary quantitative data on energy power plants and international (cross-border) interconnections in South America; binational hydroelectric power plants in South America; exchanges of electric power between countries; evolution of electricity consumption; private participation in generation, transmission and distribution; gas pipeline network and natural gas reserves in South America; reserves and resources for Mercosur, among others. Data and information related to electricity, natural gas, oil, uranium and coal resources and reserves are presented respectively.

Next, Argentina (section 3.1), Bolivia (section 3.2), Brazil (section 3.3), Paraguay (section 3.4), Uruguay (section 3.5) and Venezuela (section 3.6). At country level, the following structure can be expected: (i) a brief geographical and economic presentation on the six countries previously mentioned; (ii) the consequences of privatization and institutional reform, since this is paramount when analyzing country's energy integration; (iii) presentation of energy markets existing structures, separated by electricity and oil and gas (O&G); (iv) figure showing summarized energy balance in ktoe; (v) detailed electricity sector installed capacity, with information on recent investments and projects in electricity and renewable sources; (vi) detailed presentation of binational projects, whether hydroelectric plants or gas pipelines; (vi) discussion of current public projects that have not gone forward; (vii) presentation of international (cross-border) interconnections and international trade; (viii) figure presenting energy trade, both exports and imports; (ix) information on projects and investments in the hydrocarbon sector, detailing when dealing with oil or gas; and (x) presentation of main challenges that each country faces, as well as opportunities for new ventures. When countries do not have enough information on any of the topics mentioned above, it is not going to be mentioned.

It must be noted that it is not the purpose of this chapter to make a detailed energy sector analysis at country level, nor to present the regulation of each of them, whether in electricity or O&G sector. Actually, the goal of this inquiry is to exhibit the main country's geoeconomic and electroenergetic characteristics, highlighting their relationship with regional integration. Exactly due to this reason, existing experiences in terms of energy interconnections, as well as binational HPPs and gas pipelines will be showed as well.

Regarding the energy sector of the countries being studied, it should be noted that reforms in their electric industries followed a common pattern with variations of their own: (i) vertical disintegration of the industry; (ii) transfer of assets to private sector; (iii) separation of functions from the State and creation of independent regulatory bodies, policy makers and management control; and (iv) rebalancing of tariffs and reduction/targeting of subsidies. The reforms of the energy sector in Latin America and the Caribbean (LAC) have generally implied, for many countries, the privatization of assets, the disintegration of energy chains and a conceptual change regarding ends and means in the public services formerly centralized within the State. In many cases, this has implied an increase in rates or increasing needs for subsidies. In both instances, for not prioritizing specific public policies concerning social rate and its scope, the social impact has been and still is negative, mainly after 2003, where the scenario of international energy prices is modified (CIER, 2013a).

It is important to mention that in addition to considering the energy market structure at country level, when we cope with energy integration, it is crucial to draw attention to current projects on physical infrastructure – stressing that the process of regional integration does not necessarily imply an increase of intra-bloc trade. Having said that, energy infrastructure and regional development have an intrinsic and close relationship that needs to be highlighted[65], particularly in the context of developing countries. In this way, it is important to understand how this relationship occurs, shedding some light onto the different variables that need to be taken into account.

Therefore, and ratifying the view presented in section 2.2 and subsection 2.3.1, integration is not understood by increased trade flow. From the energy point of view, deepening energy integration may lead to increased imports and exports of energy (electricity, oil and byproducts, and gas), but this is not necessarily true[66].

Considering nine South American countries over the period 1980-2005, APERGIS and PAYNE (2010) show the causality from energy consumption to economic growth and the fact that the region is among the world's leader in energy sources such as oil, natural gas, hydroelectricity and ethanol. Taking into account that these are developing countries, some of them facing shaken economic situations, investing in energy can lead to positive externalities for the other sectors of the economy.

In the energy policies context, especially considering investment in physical infrastructure, it is mandatory to emphasize the role of energy cooperation and integration[67] as alternatives to national policies aimed at energy self-sufficiency (MARES, 2008, SANTOS, 2017), by allowing a better use of resources by taking advantages of complementarities between countries (OCHOA *et al.*, 2013, RAMOS, 2016). As highlighted in subsections 2.3.1 and 2.3.2, it is necessary to overcome the narrow state-centric characteristic of most national plans of the different countries.

Table 2 presents energy and environmental indicators for Mercosur. It contains electric power consumption (kWh per capita), access to electricity (% of pop.), renewable energy

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[65] 'There is a strong relationship between the quality of energy infrastructure, competitiveness, and economic growth. (…). Blackouts and brownouts are very costly and are a disincentive to invest in manufacturing, while the investments required to provide back-up generation lead to increased costs. Fluctuations in voltage and power frequency also cause machine damage, financial and economic losses, and variations in product quality.' (YÉPEZ *et al.*, 2016:21).

[66] As noted in subsection 2.3.2, there are different dimensions of common electricity markets, namely (i) infrastructural integration; (ii) regulatory integration; and (iii) commercial integration (PINEAU *et al.*, 2004).

[67] 'Out of the different energy sources, the most promising one from a regional viewpoint is electricity. It provides multiple comparative advantages: tariff modicity, employment of consolidated technologies and other innovative ones (wind and solar) and environmental sustainability. Its largely technologically and technically dominated characteristics favour the installation of integrated transmission networks capable of guaranteeing continuous and uninterrupted supply of energy over long distances. Additionally, electricity favours the inclusion of large social segments, distant from development benefits and opportunities. Both factors explain the replacement of non-renewable and pollution-generating sources in the region since market reforms of years 1980-90.' (BIATO *et al.*, 2016: 61-62).

consumption (%), total natural resources rents (% of GDP), emission intensity GDP US$ 2010 (t/MUS$ 2010), CO_2 emissions (kt) and CO_2 emissions (metric tons per capita).

Table 2. Energy and environmental indicators for Mercosur, by country

Countries	**Electric power consumption (kWh per capita)**[1]	**Access to electricity (% of pop.)**[1]	**Renewable energy consumption (%)**[1,3]	**Total natural resources rents (% of GDP)**	**Emission Intensity GDP US$ 2010 (t/MUS$ 2010)**	**CO_2 emissions (kt)**[1]	**CO_2 emissions (metric tons per capita)**[1]
Ar	3,052	100.0	10.77	1,18	413,56	204,025	4.7
Bo	753	90.0	16.82	7,92	797,36	20,411	1.9
Br	2,601	99.7	41.81	2,91	206,30	529,808	2.6
Py	1,564	99.0	63.12	2,20	256,66	5,702	0.9
Uy	3,068	99.7	55.43	1,64	138,60	6,747	2.0
Ve	2,658	99.1	12.30	15,25[2]	766,60	185,220	6.0

Source: Own elaboration based on World Databank and sieLAC; [1] = 2014 ; [2] = 2013; [3] = % of total final energy consumption.

Electricity coverage in Latin America has increased substantially over the last decades, rising from 50% of the population in 1970 to more than 95% in 2015. The 1990s witnessed a period in which many countries had difficulties in expanding their networks, especially in isolated and rural areas. Only a combination of political efforts has made it possible to reach current situation, in addition to (i) the use of social tariffs and pro-competitive regulation; and (ii) renewable technologies are becoming a relevant solution for the rural area. Although there are high rates of electrification in the region, energy consumption is still very low in many areas – mainly rural areas (BANAL-ESTAÑOL, CALZADA and JORDANA, 2017)[68]. When it comes to electricity access, 'electricity needs to be affordable for consumers and tariffs should be adequate to allow service providers to expand the grid, as well as to operate and maintain their facilities.' (YÉPEZ *et al*., 2016: 8).

[68] It is important to take into account the fact that 'energy access issues particularly affect women and children, as well as indigenous people and AfroCaribbean populations.' (YÉPEZ *et al*., 2016: 5).

It is very clear that access to electrification occurs on a very diverse basis, which is expressed in the share of renewable energy consumption in each of the countries. Under Mercosur, Paraguay reaches about 63.12% while Argentina reaches only 10.77%. Countries such as Venezuela and Bolivia, in turn, have 15.25% and 7.92%, respectively, of share of total natural resources rents (% of GDP)[69]. Undoubtedly, in absolute terms, Brazil also stands out, but in relative terms (% of GDP), the weight of this income falls. All data is intertwined as we consider CO_2 emissions, which are related to the energy sector of the countries, as well as their other productive sectors. Once again, the relative and absolute differences between the Mercosur countries stand out.

Still with regard to renewable energy, noteworthy is the October publication of 2017 Renewable Energy Country Attractiveness Index (RECAI), which sets Argentina, Brazil and Uruguay in 11th, 17th and 35th respectively. Argentina and Uruguay have improved their position when compared with a previous index, while Brazil has worsened[70].

Table 3 shows production, consumption and energy surpluses and deficits, by country. The total production (Mtoe) and consumption (Mtoe) of Mercosur accounted for 74.5% and 80.6% of the total in South America (SA), respectively. In addition, considering only Mercosur, Brazil accounts for 49.6% of production and 63.6% of consumption, while Uruguay accounts for only 0.5% of production and 1.1% of consumption.

Table 3. Production, consumption and energy surpluses and deficits, by country

Country	Production (Mtoe)	Consumption (Mtoe)	Surplus/Deficit (Mtoe)	Surplus/Deficit (% Consumption)

[69] As previously argued, a significant challenge arises within Mercosur, given the entrance of Venezuela and Bolivia – since the latter has its energy production mainly based on natural gas and the former in crude oil and by-products. On the other hand, Mercosur founding members have a predominantly hydroelectric profile. Still, it is possible to see that the recent entrance of both Venezuela and Bolivia contributes positively to ensuring a bigger diversification of Mercosur energy matrix and power generation mix.

[70] See: http://www.ey.com/gl/en/industries/power---utilities/ey-renewable-energy-country-attractiveness-index-our-index.

Ar	73	87	-14	-16%
Bo	23	9	14	156%
Br	286	299	-13	-4%
Py	7	5	2	40%
Uy	3	5	-2	-40%
Ve	185	65	120	185%
Mercosur	**577**	**470**	**107**	**23%**
Cl	14	37	-23	-62%
Co	126	35	91	260%
Ec	30	14	16	114%
Gy	0	1	-1	-100%
Pe	26	25	1	4%
Su	1	1	0	0%
SA	**774**	**583**	**191**	**33%**

Source: Own elaboration based on CIER (2017b) and MME (2016).

It is also worth noting that the positive balance presented by Mercosur (107 Mtoe) is strongly influenced by the presence of Bolivia (+156%) and Venezuela (+185%)[71]. The other extra-Mercosur countries in South America only produce 197 Mtoe and consume 113 Mtoe, respectively 34.1% and 24.0% of Mercosur's values. Due to its relative size, Chile stands out as a country with high external dependence on energy (-63%).

Exchanges of electric power between countries (GWh) are presented in **Table 4**. On the total exports, Paraguay stands out, accounting for 41,450 GWh (93.1%) of total exports from South America. On the import side, Brazil (34,947 GWh, 78.5%) and Argentina (9,021 GWh, 20.3%) stand out.

Table 4. Electricity exchanges, between countries, in GWh (2015)

Countries	Ar	Br	Co	Ec	Py	Pe	Uy	Ve	Total imports	% imports

[71] Venezuela exported slightly above 180% of its energy needs (MME, 2016).

Ar		229	-	-	7,479	-	1,313	-	9,021	20.3%
Br	56		-	-	33,971	-	7	913	34,947	78.5%
Co	-	-		45	-	-	-	-	45	0.1%
Ec	-	-	457		-	55	-	-	512	1.1%
Uy	2	-	-	-	-	-		-	2	0.0%
Ve	-	-	3	-	-	-	-		3	0.0%
Total exports	58	229	460	45	41,450	55	1,320	913	44,530	100.0%
% exports	0.1%	0.5%	1.0%	0.1%	93.1%	0.1%	3.0%	2.1%	100.0%	-

Source: Own elaboration based on CIER (2017b)

Mercosur countries have played a leading role in electric power exchanges in South America. They account for 43,970 GWh (98.8%) of exports and 43,973 GWh (98.8%) of electricity total imports from South America. In other words, they are not only the main sources, but also the main destinations of electricity in transit in the region. This is also one of the main reasons why this present thesis focuses on Mercosur countries, and not on UNASUR countries.

Although the accession of potentially interesting new countries from the point of view of energy exchanges is positive for the energy integration of the region, it is important to consider that the more countries participate in the arrangement, the greater the existing asymmetry. Therefore, given the recent enlargements that have taken place in Mercosur, RODRIGUES (2012a) sheds light onto the need of (only) analyzing institutional and regulatory issues on energy integration within and between Mercosur countries, following HIRA (2003) and VARELA's (2015) lead.

Figure 5, **Figure 6, Table 5**, **Table 6** and **Table 7** come from CIER (2017), whose base-year is 2015. The document is entitled 'Energy Information Synthesis of the CIER Countries: Information on the energy sector in South American, Central American and the Caribbean countries - Year 2015'.

Figure 5 shows that cross-border interconnections are spatially concentrated in the Andes or Southern Cone, what justifies why different authors and project methodologies analyze South American energy integration divided into two large blocs of countries. This is the case of the famous CIER Project 15, which divides South America into Andean Community (Bolivia, Colombia, Ecuador and Peru) and Mercosur (Argentina, Brazil, Chile, Paraguay and Uruguay)[72]. In the following figure, it is possible to see in detail whether the interconnections are operating/existing, under construction or under study. In addition, we present the operating and under study HPPs.

[72] Although there is a footnote in the project mentioning that countries that participate in the Mercosur and Andean Community (CAN) groups are not necessarily members of the homonymous commercial unions, the fact is that this methodological decision contributes to hinder regional comparative studies. This happens because there is no formal methodological accuracy when it comes to studying and evaluating such countries. This positioning confirms the fact that Venezuela is not considered in the region of South America. The project report (CIER, 2011) justifies that it was not possible to include Venezuela in the study due to the deadline limits for data delivery. Furthermore, CIER 15 makes another conceptual mistake in referring to Mercosur and CAN as ‘commercial unions’.

Figure 5. Power plants and international interconnections in South America

Source: CIER (2017b).

For South America, CIER National and Regional Committees provides the data, as well as:

- Argentina: Ministry of Energy and Mining (MINEM);
- Bolivia: National Load Dispatch Committee (CNDC);
- Brazil: Ministry of Mines and Energy (MME);
- Colombia: Mining and Energy Planning Unit (UPME);
- Paraguay: National Electricity Administration (ANDE);
- Perú: Ministry of Energy and Mines (MINEM); y
- Uruguay: National Administration of Power Plants and Electric Transmissions (UTE).

It is observed that almost all countries have interconections with a neighboring country. However, when analyzing electricity exchanges between countries, they do not seem relevant.

Table 5 shows the main binational hydroelectric power plants in South America. Again, all of them are located in Mercosur countries, particularly in the Southern Cone.

Table 5. Binational Hydroelectric Power Plants in South America

Ref.	Countries	HPP	River	Installed Capacity (MW)	Status
A	Br-Py	Itaipu	Paraná	14,000	In operation
B	Ar-Uy	Salto Grande	Uruguay	1,890	In operation
C	Ar-Py	Yacyretá	Paraná	3,200	In operation
D	Ar-Br	Garabí-Panambí	Uruguay	2,200	Under study
E	Ar-Py	Corpus Christi	Paraná	3,400	Under study

Source: Adapted from CIER (2017).

Binational plants are detailed by countries involved in the project, river, installed capacity (MW) and status. The weight of Itaipu (14,000 MW) is evident, corresponding to 56.7% of the total installed capacity of binational hydroelectric power plants in South America. In addition, it should be noted that Garabí-Panambí (2,200 MW) and Corpus (3,400 MW) are still under study, so they do not contribute to the generation of electricity and income for the countries of that region.

Table 6 features the power plants and international interconnections in South America showed in **Figure 5**. This table shows countries involved, location of the enterprise, voltage (kV), installed capacity (MW) and current status with frequency. It is clear that countries of the Andean region (Colombia, Ecuador, Peru and Venezuela) have a frequency of 60 Hz such as Brazil, but unlike Argentina, Bolivia, Chile, Paraguay and Uruguay, whose systems operate at 50 Hz[73].

Table 6. Power plants and international interconnections in South America

Ref.	Countries	Location	Voltage (kV)	Installed capacity (MW)	Status
1	Co-Ve	Cuestecita (Co) – Cuatricentenario (Ve)	230	150	Operating (60 Hz)
2	Co-Ve	Tibú (Co) – La Fría (Ve)	115	36	Operating (60 Hz)
3	Co-Ve	San Mateo (Co) – El Corozo (Ve)	230	150	Operating (60 Hz)
4	Co-Pa	Cerromatoso (Co) – Panamá (Pa)	(Co)	300	Under study (HDVC)
5	Co-Ec	Jamondino (Co) – Pomasqui (Ec)	230	250[1]	Operating (60 Hz), 4 circuits
6	Co-Ec	Jamondino (Co) – Pomasqui (Ec)	230	250[1]	Under construction (60 Hz)
7	Co-Ec	Ipiales (Co) – Tulcán (Ec)	138	35/113	Operating (60 Hz)
8	Ec-Pe	Machala (Ec) – Zorritos (Pe)	230	110	Operating (60 Hz)
9	Br-Ve	Boa Vista (Br) – El Guri (Ve)	230/400	200	Operating (60 Hz)
10	Bo-Pe	La Paz (Bo) – Puno (Pe)	230/220	150	Under study (50/60 Hz)
11	Br-Py	Itaipu	500/220	14,000	Operating (60/50 Hz)
12	Br-Py	Foz de Iguazú (Br) – Acaray (Py)	220/138	50	Nonoperating (60/50 Hz)
13	Ar-Py	El Dorado (Ar) – Mcal. A. López (Py)	220/132	30	Operating (50 Hz)
14	Ar-Py	Clorinda (Ar) – Guarambaré (Py)	220	90	Operating (50 Hz)
15	Ar-Py	Yacyretá	500	3,200	Operating (50 Hz)
16	Ar-Br	Rincón S.M. (Ar) – Garabí (Br)	500	2,000/2,200	Operating (50/60 Hz)
17	Ar-Br	P. de los Libres(Ar) – Uruguayana(Br)	132/230	50	Operating (50/60 Hz)
18	Ar-Uy	Salto Gde. (Ar) – Salto Gde. (Uy)	500	1,890	Operating (50 Hz)
19	Ar-Uy	Concepción (Ar) – Paysandú (Uy)	132/150	100	Emergency Op. (50 Hz)
20	Ar-Uy	Colonia Elia (Ar) – San Javier (Uy)	500	1,386	Operating (50 Hz)
21	Br-Uy	Livramento (Br) – Rivera (Uy)	230/150	70	Operating (60/50 Hz)
22	Br-Uy	Pte. Médici (Br) – San Carlos (Uy)	500	500	Operating (60/50 Hz)
23	Ar-Cl	CT TermoAndes (Ar) – Sub.Andes (Cl)	345	633	Operating (50 Hz)
24	Ar-Bo	Yaguacua (Bo) – Tartagal (Ar)	500		Under study

Source: CIER (2017b); [1] = double circuit; HVDC = high-voltage, direct current.

[73] As already mentioned, this is one of the reasons why it is usual to model the region by dividing the Andean area with that of the Southern Cone, as already highlighted.

Table 7 shows the evolution of electricity consumption during 1990-2015, in kWh/inhabitant. It varies widely among Mercosur countries and has grown significantly over the last decades.

Table 7. Evolution of electricity consumption, in kWh/inhabitant (1990-2015)

Country	1990	1995	2000	2005	2010	2015
Ar	1,459	1,882	2,438	2,871	3,367	3,575
Bo	284	378	468	521	697	849
Br	1,554	1,886	2,142	2,402	2,821	2,966
Py	641	890	1,044	1,212	1,627	2,137
Uy	1,521	1,934	2,386	2,518	2,838	3,146
Ve[1]	2,837	3,226	3,697	3,940	4,002	4,272
Mercosur[2]	**1,383**	**1,699**	**2,029**	**2,244**	**2,559**	**2,824**
Cl[3]	1,051	1,763	2,748	3,358	3,648	4,028
Co	1,058	1,088	983	1,058	1,209	1,371
Ec	589	734	839	1,147	1,408	1,636
Pe	444	558	776	937	1,223	1,536
AS	**1,422**	**1,674**	**1,946**	**2,208**	**2,564**	**2,755**

Source: Own elaboration based on CIER (2017); No data for Guyana and Suriname. [1] = Correspond to 2014, the latest information available; [2] = Calculated as a means of Ar, Bo, Br, Py, Uy e Ve; [3] = Does not include Central Salta located in Argentina.

Table 8 shows the profile of generation, transmission and distribution of electricity by country. Given the heterogeneity existing within the territory, both in terms of resources and in the political orientation, the adopted regulatory framework has varied according to each specific case. The nature of each activity changes greatly from country to country, especially in the generation sector.

In general, countries can be divided into two groups. First, there is the group made up of countries with the greatest State intervention or participation. This is the case of Bolivia, Paraguay and Uruguay. However, this group also presents several differences within. In the second group, Argentina and Brazil can be found. The two countries with the greatest territorial extension on the subcontinent have a strong State participation in common in regulatory terms, with constant changes in normative aspects. The participation in the ownership of companies varies in the three segments. Private, public companies and even some of mixed capitals coexist, although the first group is the largest among the three of them.

Table 8. Generation, transmission and distribution of electricity markets, by country

Country	Generation		Transmission		Distribution		
	Organization	**Wholesale market regime**	**Organization**	**Network (km)**	**Organization**	**Tariff schedule**	**Clients (millions)**
Ar	Monopsony[2]	Special	Trunk system: Monopoly (Transener)	34,292	Monopoly by region	Revenue Cap and PriceCap	15.8
Bo	Oligopoly[2]	Ordinary	Oligopoly	4,466	Monopoly by region	Price-Cap	2.4
Br	Oligopoly[2]	Special	Oligopoly	135,252	Monopoly by region	Price-Cap	80.7
Py	Monopoly (ANDE)	Special	Monopoly (ANDE)	5,653	Monopoly (ANDE)	Cost of service	1.3
Uy	Partial monopsony[3]	Ordinary	Monopoly (UTE)	4,963	Monopoly (UTE)	Price-Cap[1]	1.3
Ve	Monopoly (Corpoelec)	-	Monopoly (Corpoelec)	18,000	Monopoly (Corpoelec)	Revenue Cap and PriceCap	-

Source: Own elaboration based on AZUAJE and MORALES (2015) and COCIER (2016, 2017a, 2017b); [1] = not implemented; [2] = public and private property; [3] = mostly public.

Based on recent Colombian Committee of the CIER (COCIER) reports, a brief summary of each segment is presented. As previously mentioned, the generation activity shows very heterogeneous models according to each country. Competition with both private and public companies is usually the rule, although in some cases it is more oligopolistic due to high levels of concentration. In other cases, there are situations of monopsony with the existence of a single buyer that puts the bidders in a situation of lower market power (COCIER, 2016).

The organization of the transmission activity is country by country, although there are certain similarities between some cases. Bolivia and Brazil[74] are characterized by being

[74] Like Chile, Colombia and Peru.

oligopolistic markets where concessioned companies can be both private and public. In some cases, they also differ according to voltage levels. Paraguay, Uruguay and Venezuela[75] have in common that the transmission segment is carried out by publicly owned monopolies vertically integrated. Finally, Argentina has a monopoly, but with regional separation. This is due to the fact that transport by extra high voltage is carried out only by one company (TRANSENER), while the so-called trunk transmission is carried out by different companies that separate their areas according to geographical criteria (COCIER, 2017a).

In some cases like Bolivia and Uruguay[76], the distribution is an ordinary regime characterized by the existence of supply contracts between market generators and distributors (except in Bolivia, which although regulated have not yet been implemented) and a spot market, generally valued at marginal cost. Argentina[77] originally had ordinary schemes, but then it started changing as various regulations were implemented. Contracts between private parties are no longer allowed and transactions can only be carried out with the CAMMESA operator at fixed prices. Brazil, on the other hand, has the contract market divided into two environments, regulated (ACR) and free (ACL), and also has four different spot markets according to the region (N, NE, S, SE). Paraguay and Venezuela are divergent from the rest since they do not directly have a wholesale market regime because there is a single monopolistic company and vertically integrated in all activities (ANDE and Corpoelec). In Argentina and Brazil[78] most of the capital are private, while in Bolivia and Ecuador it is public. Paraguay, Uruguay and Venezuela would be the extremes of the region, since the activity is carried out by a single public capital company in the three cases (COCIER, 2017b).

Table 9 presents a snapshot of private participation by subsector in December 2010, showing the heterogeneity of market composition across Latin American countries. It is possible to argue that most countries tend to have a relevant degree of public participation, with state-owned utilities as key players in the three sub-sectors (BALZA *et al.*, 2013).

Table 9. Private participation in generation, transmission and distribution, in %

[75] Like Ecuador.
[76] Like Colombia and Peru.
[77] Like Ecuador.
[78] Like Peru.

Country	Generation	Transmission	Distribution
Ar	73	100	66
Bo	35	87	82
Br	38	14	70
Py	0	0	0
Uy	3	0	0
Ve	0	0	0

Source: BALZA *et al*. (2013); Venezuela started the process of re-nationalizations in 2007 and Bolivia in 2011. In Paraguay and Uruguay, distribution refers to billing by private utilities.

Evidences based on analyzes of developing countries in the 1980s and early 2000s highlight that good regulatory governance has a positive and statistically significant effect on per capita generation capacity (CUBBIN and STERN, 2006), and that performance improvements resulting from private participation depend on the presence of an effective regulatory regime that stimulates management (ZHANG *et al*., 2008). However, it is important to note that the effect of privatization on electricity prices is not clear (NAGAYAMA, 2007, 2009).

Privatization itself does not necessarily lead to better results (such as improved labor productivity, higher capital utilization, increased generating capacity, or higher output) unless it is coupled with independent regulation (ZHANG *et al*., 2008). We are completely in line with this argument. Nevertheless, there are studies that find that privatization has increased access to electricity services in Argentina, Bolivia, Mexico, and Nicaragua, particularly for lower income groups (MOOKHERJEE and McKENZIE, 2005), while others studies analyzing 10 Latin American countries (LAC) find mixed results (ANDRES *et al*., 2008).

Figure 6 and **Table 10** show gas pipeline networks and natural gas reserves in South America detailing whether they are operating/existing, under construction, in project or under study. In addition, the gas basins of the region are presented. **Table 10** details the countries involved in each gas pipeline network, location of the project, diameter (inch), capacity (Mm^3/d) and current status. As can be seen from the table, many gas pipelines are (i) operating in limited service; (ii) nonoperating; or (iii) in interruptible operation.

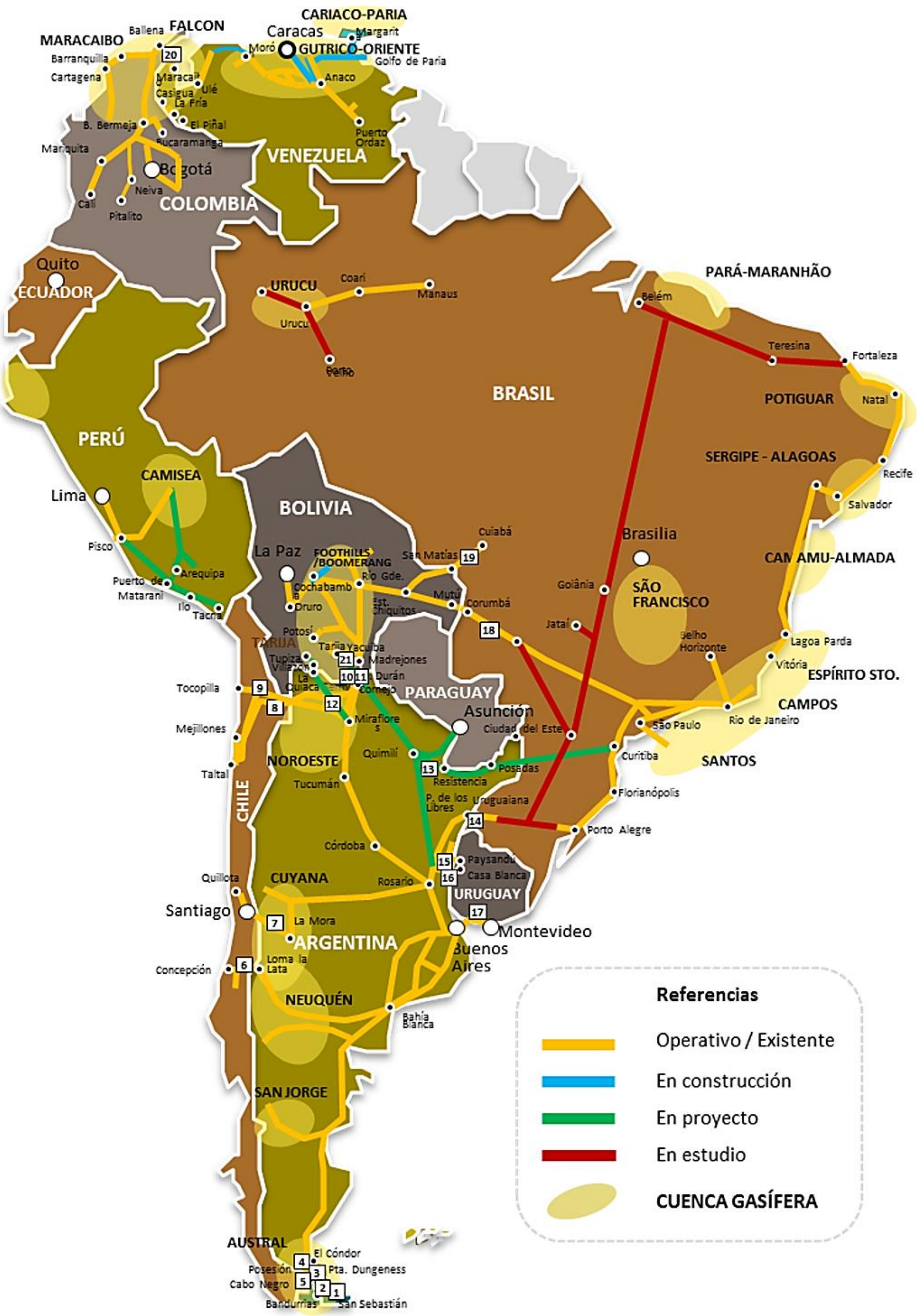


Figure 6. Gas pipeline networks and natural gas reserves in South America

Fonte: CIER (2017b).

Table 10. Gas pipeline networks and natural gas reserves in South America

Ref.	**Countries**	**Gas pipeline**	**Diameter (Inch)**	**Capacity (Mm^3/d)**	**Status**
1	Ar-Cl	San Sebastián (Ar) – Pta. Arenas (Cl) (Bandurria)	10	4	Existing (sin. op)
2	Ar-Cl	Batería de Recepción 7 – T. del Fuego	6	1,5	Operating
3	Ar-Cl	Pta. Dungeness (Ar) – C. Negro (Cl) (Dungeness)	8	2	Existing (sin. op)
4	Ar-Cl	El Cóndor (Ar) – Posesión (Cl)	12	2	Existing (sin. op)
5	Ar-Cl	Pta. Magallanes (Ar) – Posesión (Cl)	18	1	Existing (sin. op)
6	Ar-Cl	L. La Lata (Ar) – Concepción (Cl) (Gas Pacífico)	24-20	3,5	In operation on the Argentine side
7	Ar-Cl	La Mora (Ar) – Santiago (Cl) (Gasandes)	24	10	In interruptible operation
8	Ar-Cl	Cnel. Cornejo (Ar) – Mejillones (Cl) (Gasatacama)	20	9	Existing (nonoperating)
9	Ar-Cl	Gasod. Norte (Ar) – Tocopilla (Cl) (Norandino)	20	8,5	In interruptible operation
10	Ar-Bo	Ramos (Ar) – Bermejo (Bo)	8-13	1,2	Operating
11	Ar-Bo	Campo Durán (Ar) – Madrejones (Bo)	24	7	Existing (nonoperating)
12	Ar-Bo	Miraflores (Ar) – Tupiza (Bo) (Puna)			Under sudy
13	Ar-Br	Cnel. Cornejo (Ar) – S. Paulo (Br)			In project
14	Ar-Br	Aldea Brasilera (Ar) – Uruguayana (Br)	24	10-15	In interruptible operation
15	Ar-Uy	Gto. Entrerriano (Ar) – Paysandú (Uy) (Del Litoral)	10	1	Operating in limited service
16	Ar-Uy	Gto. Entrerriano (Ar) – Casa Blanca (Uy)	16	5-2	Existing (nonoperating)
17	Ar-Uy	Bs. Aires (Ar) – Montevideo (Uy) (C. del Sur)	24-18 (1)	6	Operating in limited service
18	Bo-Br	Río Grande (Bo) – S. Paulo (Br)	32	30	Operating
19	Bo-Br	Río Grande (Bo) – Cuiabá (Br) (GASBOL)	18	2,8	Operating
20	Co-Ve	Est. Ballena (Co) – Maracaibo (Ve) (Transcaribe)	18	4,2	Operating
21	Ar-Bo	Campo Durán (Ar) – Campo Grande (Bo) (Juana Azurduy)	24-32	27,7	Operating

Source: CIER (2017b).

Despite the region potential for gas integration, none of the LAC countries is explicitly pitching for the construction of integration gas pipelines in the short or medium term. Only Bolivia, after the construction of a smaller high capacity pipeline to increase gas shipments to Argentina, raises the possibility to increase the capacity of shipments to Brazil. However, it is a currently remote possibility. Its main problem is to develop and produce on time all the gas committed in its contract with Argentina. The trend is assured today in the export-import of LNG, which calls into question the need for more capital-intensive investments in new gas pipelines (D'APOTE and CASTAÑOS, 2016, CAF, 2013c) and makes room for a new regional dynamic in terms of potential LNG trade between countries**.**

Table 11 below presents data such as oil reserves (Gbbl), natural gas reserves (Gm^3), uranium reserves (kt), coal reserves (Mt), hydropower resources (TWh), power plant capacity (GW) and refining capacity (kbbl/d). However, it should be noted that due to the great uncertainty about proven, possible and probable reserves, as well as the existing ones with respect to unconventional resources (such as shale gas)[79], it becomes almost impossible to envision a clear picture for gas integration in the region.

[79] Especially for those with intention and/or decision to invest in their exploitation.

Table 11. Reserves and resources for Mercosur, by country (2015)

Countries	Oil reserves (Gbbl)[1]	Natural gas reserves (Gm^3)[1]	Uranium reserves (kt)[2]	Coal reserves (Mt)[1]	Hydropower resources (TWh)[3]	Power plant capacity (GW)	Refining capacity (kbbl/d)
Ar	2.4	332.0	19.0	500.0	169.0	35.8	657.0
Bo	0.4	281.0	-	-	126.0	2.4	69.7
Br	13.0	429.0	309.0	7039.0	1250.0	140.9	2,278.0
Py	-	-	-	-	85.0	9.8	7.5
Uy	-	-	-	-	10.0	3.9	50.0
Ve	300.9	5,617.0	-	479.0	261.0	31.4	1,303.0
Mercosur	316.7	6,659.0	328.0	8,018.0	1,901.0	224.2	4,365.2
SA	327.7	7,256.0	333.0	14,987.0	2,842.0	277.9	5,599.0
% Mercosur/SA	96.6%	91.8%	98.5%	53.5%	66.9%	80.7%	78.0%
World	1,698.0	186,875.0	6,306.0	891,531.0	15,955.0	6,000.0	97,227.0
% Mercosur/World	18.7%	3.6%	5.2%	0.9%	11.9%	3.7%	4.5%

Fonte: Own elaboration based on CIER (2017b), MME (2016), British Petroleum (BP) and World Energy Council (WEC); [1] measured; [2] proved and inferred; [3] technically exploitable; bbl = barrel.

Based on the data, the challenge of adding value to regional energy resources stands out. Considering South America, Mercosur has 96.6% of oil reserves, 91.8% of natural gas reserves, 98.5% of uranium reserves, 53.5% of coal reserves, 66.9% of hydropower resources, 80.7% of power plant capacity and 78.0% of refining capacity. In Mercosur, Argentina, Brazil and Bolivia catch the eye[80]. Venezuela has 95.0% of oil reserves, 84.4% of natural gas reserves, 13.7% of hydropower resources, 14.0% of power plant capacity and 29.8% of refining capacity. Brazil has 94.2% of uranium reserves, 87.8% of coal reserves, 65.8% of hydropower resources, 62.8% of power plant capacity and 52.2% of refining capacity. Argentina stands out because of having 8.9% of hydropower resources, 16.0% of power plant capacity and 15.1% of refining capacity.

Table 12 shows proven natural gas reserves in trillions of cubic feet (TCF) by country, for the period between 1990 and 2015. In 2015, Mercosur has 92.5% of proven natural gas reserves in South America, especially Venezuela (84.4% of the total). Beyond

[80] It is noteworthy that Paraguay and Uruguay do not have reserves of oil, natural gas, uranium and coal. This makes the range of energy generation possibilities in these countries more narrow, which may put pressure on their energy security.

Mercosur countries, Peru and Colombia stand out with 5.7% e 1.9% of total proven natural gas reserves in South America in 2015, respectively.

Table 12. Proven natural gas reserves, by country, in TCF (1990-2015)

Country	**1990**	**1995**	**2000**	**2005**	**2010**	**2015**
Ar	23.3	21.9	27.5	15.5	12.7	11.7
Bo	3.9	4.6	24.0	26.1	9.9	9.9
Br	4.2	5.3	7.8	10.6	14.7	15.0
Ve	121.1	143.4	146.5	152.5	192.7	198.4
Mercosur	152.5	175.2	205.8	204.7	230.0	235.0
AS	168.0	190.1	219.2	220.3	247.9	254.0
% Mercosur/AS	90.8	92.2	93.9	92.9	92.8	92.5

Source: CIER (2016); TFC = trillions of cubic feet.

Regarding the available energy data for the region, in addition to CIER's data and reports, the recent creation of the Latin America and the Caribbean Energy Information System (sieLAC-OLADE) in 2017 should be mentioned[81]. The sieLAC-OLADE is an energy information platform that allows OLADE to integrate, process and disseminate official statistical, socioeconomic, legal and documental information concerning the energy sector of its 27 member countries, based on standardized methodologies and concepts that allow consolidation of information at the national, subregional and regional levels.

In the following subsections, we will make a brief comparative analysis of several qualitative and quantitative variables in order to summarize projects that are related to regional integration and recent energy policies in the different Mercosur countries. Thus, we sought to shed light onto 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.

3.1 Argentina

Argentina is the second largest country in South America in terms of territorial extension and the third according to the number of inhabitants (after Brazil and Colombia). Its

[81] Infographics that will be presented for each of the countries come from this database.

territory comprises 2.80 million km^2 with a very varied geography and different climates due to its latitudinal amplitude and variety of reliefs. Its economy is diversified with a large industrial and service production as well as the exploitation of natural resources. However, following the patterns of the region, the main export item comes from the agricultural primary sector, with soy being the main component. Its population comprises 43.8 million inhabitants and it has a per capita GDP of US$ 12,454.34 at current prices, which is why it is included in the segment of high-income countries.

Like other countries in the region, Argentina also undergone a recent process of privatization and institutional reform of its electricity sector. Studies find evidence that it increases both access to and quality of service (GONZALEZ-EIRAS and ROSSI, 2007) for lower income groups[82] (MOOKHERJEE and McKENZIE, 2005).

In Argentina, the Ministry of Energy and Mining (MINEM) is responsible for the policies and guidelines of the electricity sector. The regulation and supervision are in the hands of the National Electricity Regulatory Entity (ENRE), although in fact the electrical regulation is provincial (there are 24 different regulators). Wholesale Electricity Market Administrator Company (CAMMESA) manages the wholesale electrical market and the Federal Electrical Energy Council (CFEE) is responsible for the monitoring and follow-up of national and municipal governments.

With regard to electricity generation, there are private and state-owned companies utilities, Yacyretá (Ar-Py) and Salto Grande (Ar-Uy). Regarding transmission, there is the Argentine Interconnection System (SADI), with two subsystems that compose it, the High Voltage Electric Power Transport System (STAT) and the Trunk System (ST). The transmission companies are Transener (only of STAT), Transba, Transpa, Transnoa, Distrocuyo, Transnea, Transcomahue. Concerning distribution, most of the distribution companies belong to private concessionaires and each province has its own. In Buenos Aires, they are Distribution and Marketing Company of the North S.A (EDENOR), South Distribution Company S.A. (EDESUR) and Distribution Company of La Plata S.A. (EDELAP). Commercialization is controlled by CAMMESA and the studies/planning of the electricity sector are under the authority of different MINEM secretariats, such as the Secretariat of Strategic Energy Planning.

[82] They argue the same for the Bolivian case.

Regarding the hydrocarbon sector, MINEM continues to be responsible for the design of policies and guidelines. Concerning regulation and supervision, the National Regulatory Entity for Gas (ENARGAS) regulates the gas market; there is not properly an agent responsible for regulating the oil sector, with the normative competence of MINEM itself. With regard to exploration and production (E&P), the Undersecretariat of Enargas is responsible for the gas sector and the Undersecretariat for Exploration and Production of MINEM for oil. There is great participation of Fiscal Oilfields (YPF S.A.) and private companies such as *Petrobras Argentina*, *Pan American Energy Sucursal Argentina*, LLC and *Total Austral S.A.* The refining, transportation and commercialization remain within the Undersecretariat of Refining and Marketing of MINEM and private companies.

Figure 7 presents the Argentine summarized energy balance in 2015. Based on it, it can be seen that the primary supply (85,351.13 ktoe) is composed of natural gas (47,011.56 ktoe, 55.1%), crude oil (26,695.42 ktoe, 31.3%), other primaries (4,361.63 ktoe, 5.1%), hydropower (3,565.00 ktoe, 4.2%), nuclear (2,203.75 ktoe, 2.6%) and coal (1.513.77 ktoe, 1.8%). In final consumption (59,064.28 ktoe), we can see the importance of transport (18,722.94 ktoe, 31.7%), residential (15,056.74 ktoe, 25.5%) and industrial (13,400.04 ktoe, 22.7%), being 18.9% supplied by electricity. In Mercosur, Argentina corresponds to 18.0% of primary supply and 16.8% of final consumption. In the total supply, it is noted that 3.2% of crude oil, 20.3% of natural gas and 94.6% of coal are imported. 5.8% of electricity are imported and 0.04% is exported.

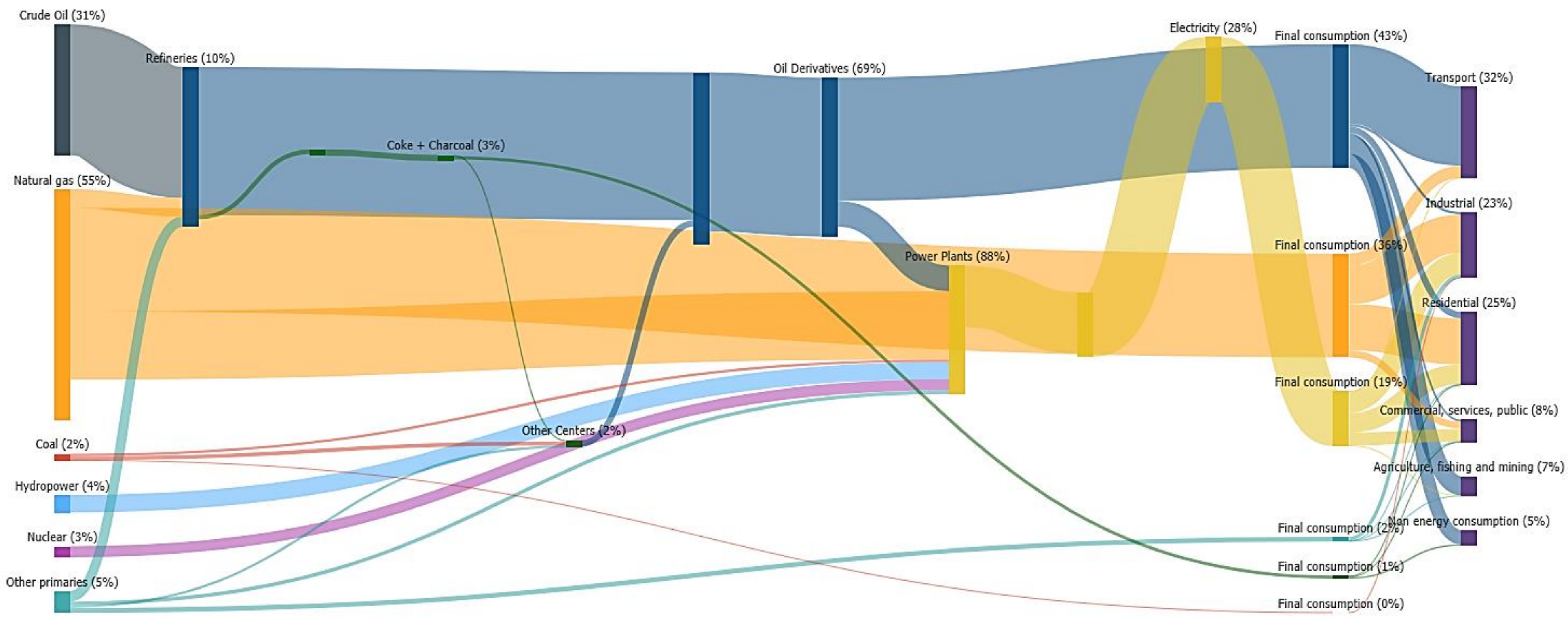


Figure 7. Argentine summarized energy balance (2015, in ktoe)

Source: sieLAC-OLADE.

Argentina's electricity sector has an installed capacity of 32,594 MW, most of which comes from conventional thermal (19,519 MW) and hydroelectric (11,108 MW) sources. It is followed by nuclear power with 1,755 MW and in terms of non-conventional renewable energy (NCRE) there is not much development, with an installed capacity of 212 MW.

According to 2017 OLADE Energy Statistics Yearbook, in terms of electricity, the life extension process of the Embalse Nuclear Power Plant is satisfactorily developed. The reconditioning will allow it to operate for a new cycle of 30 years. In addition, the plant will increase its power to 683 MWe, that is, 6% more than its current generation capacity. Regarding renewable sources, Argentina launched the 2016-2025 Renewable Energy Program (RenovAr)[83], directed to the contracting in the Wholesale Electricity Market (MEM) of electricity from renewable sources with a total requirement of 1,000 MW, under Round 1, which would be added to the energy supply of the country, divided as follows: 600 MW of wind, 300 MW of solar power, 65 MW of biomass, 20 MW of small hydroelectric projects and 15 MW of biogas. With these new additions, the country would save about US$ 300 million per year in fuel imports for electricity generation and avoid the emission of almost 2 million tons of CO_2 ($MtCO_2$) into the atmosphere annually (OLADE, 2017). This plan is part of the goal established with the law 27.191/2015[84], in which the country should count on 20% of renewable energy generation until 2025 (CIER, 2017b).

Considering South America, Argentina is actually the last country to use its water resources for electricity generation, with only about 30% of its electricity coming from water sources (half the regional average). 63% of Argentine electricity comes from thermal power plants, which mostly use gas as fuel, what represents a considerable expenditure of foreign exchange, besides being a non-renewable resource. The country has only a few large hydroelectric plants, two of which are binational: Yacyretá (with Paraguay) and Salto Grande (with Uruguay).

[83] See: http://www.eeeuu.mrecic.gov.ar/userfiles/v7/presentacion-energia-espanol-6%282%29.pdf.
[84] See: http://asades.org.ar/aspectoslegales/ley27191.pdf.

The Yacyretá Binational Entity (EBY) was created in 1973 (Treaty[85] of Yacyretá) to take advantage of the hydroelectric potential of the Paraná River. The plant has 20 turbines (3,200 MW of installed capacity). The first one went into operation in 1994 and the last one in 1998. It is represented on the Paraguayan side by National Electricity Administration (ANDE) and the Argentine side by *Emprendimientos Energéticos Binacionales S.A.* (EBISA)[86] – EBY is the dam operator. The Treaty establishes equal rights for both parties and right of each High Contracting Party, at the cost of the work, of 50% of the generated energy.

However, it should be noted that the experience of the binational hydroelectric plant of Yacyretá begins with an agreement between both countries in 1926, in which they express their interest in exploiting available hydroelectric resources in the Paraná River and the use of the Apipé Falls. In 1958, the governments signed an agreement to carry out technical studies (energy and navigability), and the Argentine-Paraguayan Joint Technical Commission of Yacyretá-Apipé was formed.

In turn, Salto Grande is a project from the late nineteenth century; it was created in 1973 (when the Treaty of Limits of the Rio de la Plata was signed) to exploit the hydroelectric potential of the Uruguay River. The first generating unit of this project came into operation in 1979, and by 1994 the project was completely paid up. It has 14 Kaplan turbines (1,890 MW of installed capacity) and is represented by CAMMESA, and the other half belonging to the Uruguayan system, administered by ADME, with the Mixed Technical Commission of Salto Grande as operator.[87]

One of its main antecedents is the Agreement of 1946 between Argentina and Uruguay by which a Mixed Technical Commission was formed. The Salto Grande exploitation led to the interconnection of the two national systems in voltage levels of 500 kV. This

[85] The process of signing international treaties is characterized by a series of formalities that in most cases involve the approval or ratification by the Congress or Legislative Assemblies of countries part of it. This formal component prevailing in Public International Law represents great advantages in terms of legitimacy, however it implies a great complexity and delay to the process, for limiting or reforming the commitments assumed (ABADIE *et al*., 2017).

[86] The Presidents of both countries signed a memorandum of understanding that includes the return of the balances of the contributions made by Argentina during the construction of the Yacyretá Hydroelectric and a plan to use the revenues of the dam to make investments and expand its generation capacity. This agreement reflects a restoration of relations between both countries, postponed years ago (CIER, 2017c).

[87] According to its official website, Salto Grande is the most important energy producer and supplies more than 50% of the energy consumed in Uruguay. Meanwhile, Salto Grande provides between 7 and 8% of the energy required in Argentina.

interconnection was finalized under the Energy Interconnection Agreement (1974), and then with the Agreement on Execution of the Energy Interconnection Agreement of 1983.

It is worth mentioning the Black Water Tunnel (*Tunel Agua Negra*) project. It is a 14 km tunnel that will pass under the Andes mountain range, connecting Argentina and Chile. It is part of a long-standing project that aims to optimize logistics and improve physical and also energy connection between the Atlantic Ocean and the Pacific[88] (CIER, 2017c).

There are two projects that have not yet been implemented involving Argentina: Garabí-Panambí (Ar-Br) and Corpus (Ar-Py). In the first case, the axis of Garabí exploitation would then be located at kilometer 863 of the Uruguay River, about 6 km downstream from Garruchos (Argentina and Brazil). The installed capacity would be 1,152 MW, distributed in 8 turbine-generator sets. The axis of the Panambí exploitation would be located at kilometer 1,016 of the Uruguay River, about 10 km upstream from the localities of Panambí (Argentina) and Porto Vera Cruz (Brazil). The installed capacity would be of 1,048 MW, distributed in 7 sets turbine-generator.[89] It is worth mentioning that in 2008 and 2009 the Brazilian company Eletrobras and Argentina's EBISA signed cooperation agreements to jointly execute an inventory study of the Uruguay River.[90]

Designed still in the 1970s, Corpus is located in the triple border between Paraguay, Brazil and Argentina. It is located on the Paraná River downstream from Itaipu and has an installed capacity of 3,400 MW. Corpus is hydrologically linked to Itaipu and Yacyretá, being designed to make optimal use of Itaipu Falls. In October 1979, the Itaipu-Corpus Tripartite Agreement was signed[91]. 'It is relevant to stress that the project is situated near highly developed basins and thereby generates benefits to the Brazilian preservation system and thermal complementarity to Argentina.' (RAMOS, 2016: 93).

Regarding international interconnections and international trade, Argentina has connections with four of its five neighboring countries. With Brazil there are two interconnections: Rincón Santa María (Ar) – Garabí (Br) of greater capacity and in force

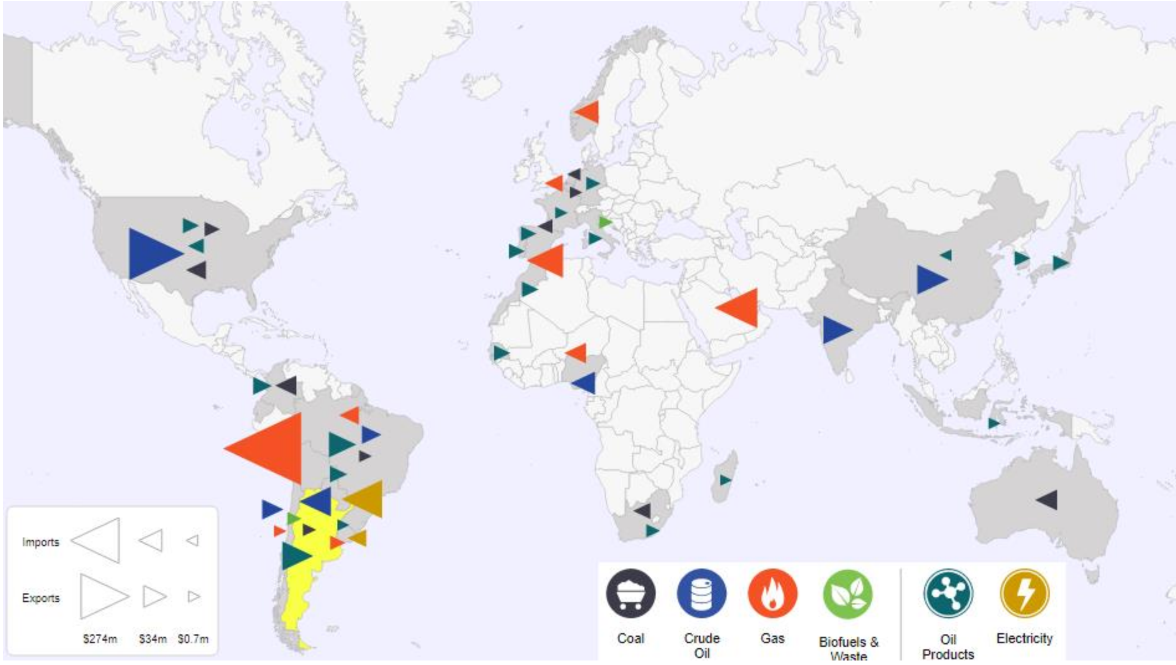
[88] See: http://www.ebitan.org/proyecto.php.
[89] See: http://garabipanambi.com.ar/obras_proyectadas.html.
[90] Eletrobras has decided to suspend technical and environmental feasibility studies on the Garabi HPP, pending the outcome of legal proceedings related to the AHE Panambi. The studies for Panambi were suspended due to the injunction of the 1st Federal Court of Santa Rosa, as a result of a public action by the Federal Public Prosecutor of the region, which was maintained by the Federal Regional Court of the 4th Region. See: http://eletrobras.com/pt/Lists/noticias/ExibeNoticias.aspx?ID=240.
[91] It results from a trilateral study whose goal was to optimize the joint use of the Paraná River (FAJARDO, 2004).

since the beginning of the last decade, and Paso de los Libres (Ar) – Uruguayana (Br), much smaller and located in the Southeast of the Province of Corrientes. With Chile, the country has the Termoandes Cobo (Ar) – Atacama (Ch) line, connected to the Interconnected System of the Norte Grande (SING). With Paraguay, there are two interconnections: the El Dorado (Ar) – Carlos López (Py) line and the Colrinda (Ar) – Guarambaré (Py) line, in addition to the binational Yacyretá plant. There are three interconnections with Uruguay: the Concepción del Uruguay (Ar) – Paysandú (Uy) line, the Colonia Elía (Ar) – San Javier (Uy) line and the Colonia Elia (Ar) – San Javier (Uy) line, as well as Salto Grande binational power plant. With Bolivia, the countries are not currently interconnected, but there is mutual interest in moving forward.

As already stressed in subsection 2.3.2, in South America there is no regional or integrated market such as the Regional Electricity Market (MER) in Central America. The exchanges that take place between Argentina and its neighbors are given (i) under a framework of previously established agreements such as the cases of binational dams; (ii) private contracts between parties in which an agreed price is compensated; or (iii) generation surpluses where companies comply with the rules of the MEM and take spot prices (COCIER, 2016).

Figure 8 shows Argentine energy trade, both exports and imports (2014, in 2000 US$). When it comes to exports, the crude oil to USA (US$ 387m; 64.4%) and India (US$ 79m; 13.1%) stands out, as well as oil products to Chile (US$ 83m; 34.9%) and Brazil (US$ 58m; 24.4%). When it comes to imports, the gas from Bolivia (US$ 861m; 66.4%), Qatar (US$ 202m; 15.6%) and Spain (US$ 132m; 10.2%) stand out, as well as crude oil from Bolivia (US$ 90m; 68.7%), and electricity from Paraguay (US$ 177m; 91.7%) and Uruguay (US$ 16m; 8.3%).

Figure 8. Argentine energy trade, both exports and imports (2014, in 2000 US$)



Source: IADB Energy Database based on UN COMTRADE.

Recently, the country signed a memorandum of understanding (MOU) with China, reaffirming the will to build two nuclear power plants in Argentina with financing from Chinese banks; one with Canadian Deuterium Uranium (CANDU) heavy water reactor technology, which is the same one used by the Embalse plant; and the other PWR with which a leap will be made towards enriched uranium and light water technology (OLADE, 2017).

Regarding the hydrocarbon sector, although 89.4% of the national oil production is distributed in 10 companies, only YPF represents almost 50% of it; in terms of natural gas production, it represents around 35% (LARA, 2017). In 2016, proven oil reserves were 2,167 Mbbl, with a twelve-year reach. The refining capacity is 632 kbbl/d, especially the production of the following derivatives: diesel oil and gasoline/alcohol.

Concerning natural gas, in 2004 the first internal supply crisis took place, and consequently supply restrictions began towards the Chilean market and the idea of integration continued to take on new forms. As the gas supply crisis in Argentina deepened (relieving the insufficiency of price adjustments as a mechanism to encourage private investment), the main adjustment variable to satisfy the growing domestic demand was the progressive increase in the cuts in gas supply to Chile. These cuts, which occasionally represented 40% in some days of 2004, reached almost 60% for longer periods in 2006 and 2007 (RUDNICK *et al*., 2007). Although the case of Chile is one of the most dramatic, Argentina progressively suspended its exports to all neighboring countries for which export infrastructure had been built, such as Brazil and Uruguay (CAF, 2013e). It is thus perceived that international relations with the neighboring country were affected by its domestic situation, which has already been presented as one of the main barriers to the progress of regional energy integration (see subsection 2.3.1).

The country has great potential in the exploitation of unconventional hydrocarbon resources, such as shale gas. For this reason, Argentina has sought to promote investments in the non-conventional oil and gas fields of Vaca Muerta, 30,000 km^2 megacamp (and which YPF owns the concession of more than 12,000 km^2), in Patagonia (south-west of the country), which is spread over the provinces of Neuquén and Mendoza**.** The area is the world's second reserve in shale gas and the fourth in shale oil. However, it should be noted that the exploitation of unconventional hydrocarbons comes surrounded by environmental questions, because (i) it uses a lot of water; (ii) pollutes the water; (iii) uses chemicals; and (iv) there is a relationship with seismic activity where wells are made.

3.2 Bolivia

The Plurinational State of Bolivia is located in the geographical center of South America with a population of 10.9 million inhabitants over an area of 1.09 million km^2. Its territory has a very varied topography, with altitudes that vary a lot. Regarding its economy, it is possible to mention the agricultural sector, which is one of the most important sectors in Bolivia, with soy being the main product. The GDP per capita at current prices is US$ 3,100.92, and it has a low average income level.

In Bolivia, it is possible to cite the newly created Ministry of Energy (ME), which has a greater focus on renewable energies[92]. Policies and guidelines of the electricity sector are

[92] This movement is in line with the goal of reducing fossil fuel consumption and increasing the indication of renewables, with particular emphasis on hydroelectric, wind, geothermal and solar energy. In this context, the geothermal project of Laguna Colorada located on the border with Chile can be highlighted. Another major challenge for the Ministry of Energy is to ensure the construction of the El Bala hydroelectric megaproject in the north of the department of La Paz, as well as the Nuclear Research and Development Center in El Alto.

the responsibility of the Vice Ministry of Electricity and Alternative Energies (VMEEA) and Vice Ministry of High Energy Technologies. Regulation and supervision are in the hands of the Electricity Control Authority (AFCSE). The National Dispatch Committee (CNDC) coordinates the dispatch.

With regard to electricity generation, there are private and state-owned companies utilities, like *Empresa Eléctrica Corani S.A.* (CORANI), *Empresa Eléctrica Guaracachi S.A.* (EGSA), *Empresa Eléctrica Valle Hermoso S.A.* (EVH), Bolivian Power Company (COBEE), *Empresa Rio Eléctrico S.A.* (ERESA), *Hidroeléctrica Boliviana S.A.* (HB), *Sociedad Industrial Energética y Comercial Andina S.A.* (SYNERGIA), *Compañía Eléctrica Central Bulo Bulo S.A.* (CECBB), *Guabirá Energía S.A.* (GBE), National Electricity Company (ENDE), ENDE Andina, *Servicios de Desarrollo de Bolivia S.A.* (SDB) y SECCO Bolivia S.A. In the same way, the production of electricity in the Isolated Systems (IS) is controlled by various companies and cooperatives, such as ENDE, *Servicios Eléctricos Tarija S.A.* (SETAR), SECCO Bolivia S.A., *Cooperativa Rural de Electricidad* Ltda. (CRE), *Gas & Electricidad S.A.* (G&E), *Cooperativa de Servicios Eléctricos de Guayaramerín Ltda*. (COSEGUA) and *Cooperativa Eléctrica Riberalta Ltda*. (CER). The transmission is up to *ENDE Transmissión S.A.* and *Interconexión Eléctrica ISA Bolivia S.A* (ISA Bolivia). Private actors are responsible for distribution, such as CRE, DELAPAZ, ELFEC, ENDE DEORURO, SEPSA, SETAR, CESSA, ENDE DELBENI, ENDE, EMDEECRUZ. Vice-Ministry of High Energy Technologies (VMATE) and the Bolivian Hydrocarbons Industrialization Company (EBIH) provide studies and planning concerning the electricity sector.

Regarding the hydrocarbons sector, there is the Ministry of Hydrocarbons (MH), formerly the Ministry of Hydrocarbons and Energy, whose regulatory agency is the National Hydrocarbons Agency (ANH). Before, there was only one ministry, or the Ministry of Hydrocarbons and Energy (MHE). Exploration and production (E&P) are the responsibility of Petrobras Bolivia (Tarija, Santa Cruz and Chuquisaca Departments), *Yacimientos Petrolíferos Fiscales Bolivianos* (YPBF), *YPBF - Andina S.A.*, *YBPF - Chaco S.A.*, *YPBF - Petroandina S.A.* Refining and transmission are the responsibility of Petrobras Bolivia (transport), *YPBF Refinación S.A.*, *YPBF Transporte S.A.*, *YPBF Transierra S.A.*, *YPBF Logistica S.A*, while the commercialization is controlled by *YPBF Aviación and Flamagas S.A.*

Figure 9 presents the Bolivian summarized energy balance in 2015. Primary supply (8,154.41 ktoe) consists of natural gas (3,813.70 ktoe, 46.8%), crude oil (3,047.58 ktoe, 37.4%), other primaries (1,081.34 ktoe, 13.3%) and hydropower (211.79 ktoe, 2.6%). In the final consumption (6,536.02 ktoe), transport (2,793.09 ktoe, 42.7%), industrial (1,654.76 ktoe, 25.3%), residential (1,135.46 ktoe, 17.4%) and agriculture, fishing and mining consumers (702.16 ktoe, 10.7%) stand out, being 10.4% supplied by electricity. Considering only the Mercosur, Bolivia corresponds to 1.7% of its primary supply and 1.9% of final consumption. It is noteworthy that 79.0% of natural gas produced are exported and that the country stands out because it has the second largest reserves of natural gas in the Southern Cone.

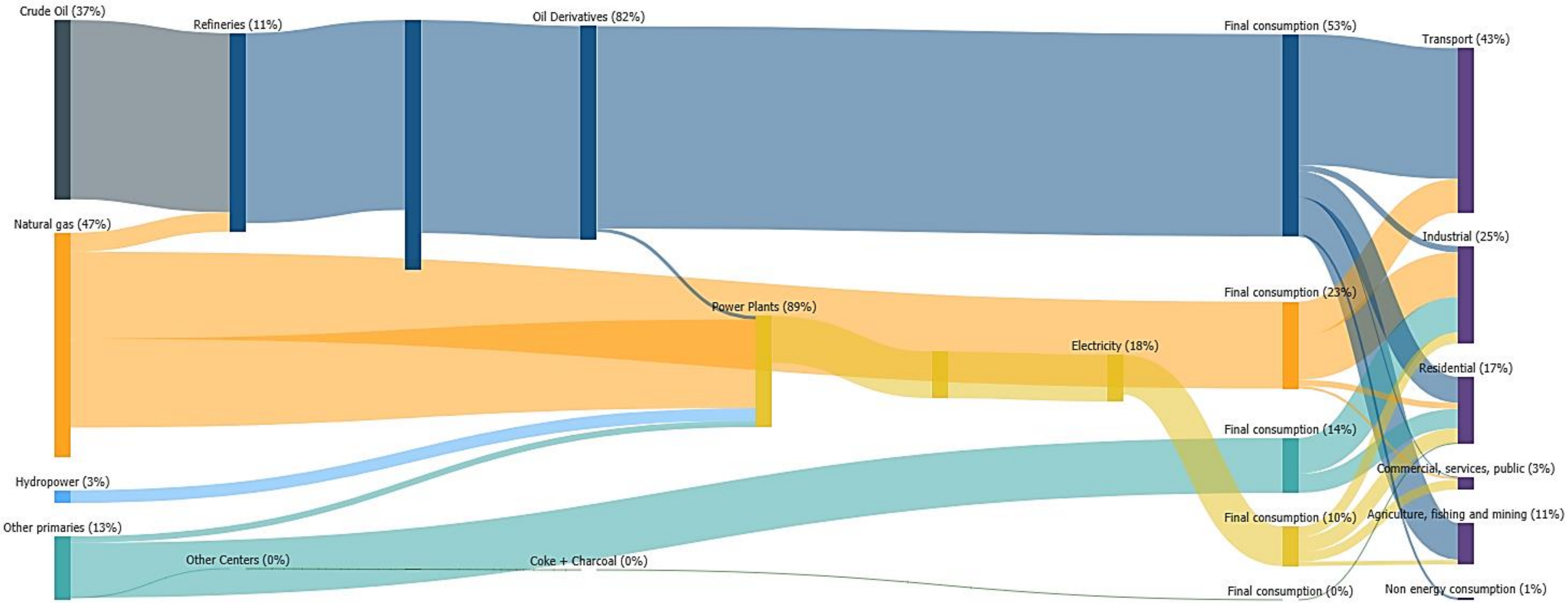


Figure 9. Bolivian summarized energy balance (2015, in ktoe)

Source: sieLAC-OLADE.

Its electricity sector is composed of two separate systems: the first one (largest) covers the entire group of generation, transmission, distribution and consumer companies of the National Interconnected System (NIS); while the second one (much smaller) is known as the group of Isolated Systems (IT)[93]. They have together an installed capacity of around 1,890 MW from 73.3% of thermal power plants and 25.4% of hydroelectric power plants.

Regarding international trade, Art. 9 of the Electricity Law of 21/12/1994[94] covers electricity exports and imports and international interconnections. It is necessary to take into account that the price of the electricity tariff includes the energy component that is determined by the price of gas, subsidized for domestic consumption. This subsidy determines a cost in the domestic market lower than that of export. There are currently no such transactions, but Bolivia plans to export electricity to Argentina as it has a surplus[95] of around 580 MW (COCIER, 2016). With respect to international interconnections, the ENDE seeks to consolidate the interconnection with Argentina, Brazil, Peru and Paraguay (COCIER, 2017a)[96].

It is noteworthy that Bolivia has no connection to its neighboring countries (although it is in the center of the subcontinent), albeit it shows interest in becoming 'South American energy heart'[97]. This isolation represents an opportunity for investments in international electrical interconnection, as well as other projects to promote regional energy integration. The Bolivian Government plans to invest around US$ 5,854 million in the 2016-2020 period and generate about 4,878 MW, of which 53,1% would be earmarked for export, according to the Economic and Social Development Plan[98].

Figure 10 shows Bolivian energy trade in terms of both exports and imports in 2014. When it comes to exports, gas to Brazil (US$ 375m; 60.6%) and Argentina (US$ 244m; 39.4%)[99] stands out, as well as crude oil to Argentina (US$ 24m; 48.0%) and China (US$

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[93] Similar to Brazilian case.
[94] See: https://www.lexivox.org/norms/BO-L-1604.xhtml.
[95] Most of this surplus is from the natural gas supply, but there is an inventoried hydroelectric potential of over 30 GW (RAMOS, 2016).
[96]It is believed that interconnection with Argentina will be completed by 2018.
[97]In different occasions, it is mentioned the interest in generating surpluses of electricity production to export. This decision is closely related to the diversification of the country's own sources of income. It is evident in the Economic and Social Development Plan 2016 - 2020, Pillar 7 (Sovereignty over our natural resources). See: http://www.planificacion.gob.bo/pdes/.
[98] See: http://www.planificacion.gob.bo/pdes/.
[99] In 2015, trade movements from Bolivia to Argentina was 5.8 bcm and 10.4 bcm to Brazil. In the same year, Bolivia produced 20.3 bcm, while Argentine and Brazil produced 36.5 bcm and 23.1 bcm, respectively (BP, 2017).

20m; 40.0%). When it comes to imports, we can mention oil products from Brazil (US$ 8m; 80.0%) and Peru (US$ 1m; 10.0%).

Figure 10. Bolivian energy trade, both exports and imports (2014, in 2000 US$)

Source: IADB Energy Database based on UN COMTRADE.

Regarding regional integration, although the country does not have international interconnections, it participates in one of the most famous cases of bilateral project in the region: the Bolivia-Brazil Gas Pipeline (GASBOL)[100]. Being the central axis of the bilateral relations between both countries [101], Bolivia has exported nearly two thirds of its natural gas production since 1999, accounting for about half of the country's tax revenues and generating most of its foreign currency denomination (BIATO, 2016). In addition, Brazilian imports of Bolivian gas corresponded to 30% of the total Brazilian market supply in 2015 (CNI, 2016)[102]. It is noteworthy that the *Transportadora Brasileira*

[100] See **Figure 6**, where the GASBOL and Lateral-Cuiabá gas pipeline are located. The Cuiabá branch was built to supply the local thermoelectric plant (Mário Covas TPP) and has a separate supply contract. The Mato Grosso's Gás Occidente is responsible for this pipeline transportation.
[101] As it is Itaipu Binacional, in the case of Paraguay.
[102] The volumes imported by Petrobras reached the contractual maximum, which is around 30 million m³/day, being 80% take or pay (24 million m³/d), of which Petrobras pays or does not use natural gas. It

Gasoduto Bolívia-Brasil S.A. (TBG) owns and operates the Brazilian side and Gas TransBoliviano S.A. (GTB) owns and operates the Bolivian side.[103] See **Appendix C**.

With a total length of 3,150 km, it has its origin in Bolivia (Santa Cruz de La Sierra). Its Bolivian extension consists of 557 km and, when entering Brazilian territory through Corumbá-MS, it travels 2,593 km inwards, passing through 136 Brazilian municipalities in five states: Mato Grosso do Sul, São Paulo, Paraná, Santa Catarina and Rio Grande do Sul. At a cost of US$ 2.15 billion (US$ 1.6 billion in Brazil and US$ 400 million in Bolivia), its transportation capacity is of 30.08 MMm^3/d with a 20-year gas supply period.[104] Project funding involved four multilateral agencies and had, in addition, BNDES participation (FRANÇA, 2015), being divided into three sections: Corumbá-Paulínia (North), Paulínia-Guararema, and Paulínia-Canoas (South).

In 2006, under the government of Evo Morales, there was the 'nationalization' episode of the Bolivian subsidiary of Petrobras[105], which led Brazil to diversify its sources of supply, whether domestic or foreign. Such an event occurred in Bolivia as a consequence of three contexts: (i) in the political context, there was a perception that foreign investors captured too much of generated gas rent without allowing a way to improve Bolivian economic situation; (ii) in the economic context, especially since 2005, the international oil prices scenario changed drastically, lowering the price of gas in different international markets; (iii) in the technological context, technological improvements in the liquefied natural gas (LNG) chain led to a decrease in the offer prices of this product.

As a consequence, Supreme Decree N. 28,701/2006 was issued[106] by President Evo Morales, which reversed the privatizations that took place in the 1990s in the hydrocarbon sector. Despite pressures from different sectors of the Brazilian public sphere, President Lula da Silva opted for the negotiation process and signed new contracts that guaranteed the gas supply and preserved Petrobras' main ventures in Bolivia, despite the reduction of its profit margins (FUSER, 2010, 2015). However, it is important to note that this breach of trust made it difficult and/or unfeasible for the negotiation of new gas

should be noted that the construction of GASBOL was one of the great developers of the natural gas market in Brazil.

[103] TBG is controlled by Petrobras and GTB by YPFB since May 1, 2008.

[104] See: http://www.tbg.com.br/pt_br/o-gasoduto/informacoes-tecnicas.htm.

[105] The breach of contract was euphemistically treated as 'contract migration', since Brazil needed imports of Bolivian gas, since it supplied about 50% of the national demand (BIATO, 2016).

[106] See: https://www.lexivox.org/norms/BO-DS-28701.xhtml.

prospecting contracts in Bolivia by international oil companies, it has shaken relations between Brazil and Bolivia to date too. In this sense, Bolivia's natural gas reserves have been reduced, which could threaten the renewal of the Gas Agreement in 2019 (BIATO, 2016).

Considering this period of shaken negotiations with its neighbor, since 2006, with the discovery of reserves in the Brazilian Pre-salt layer, a natural gas self-sufficiency was projected for Brazil. However, so far, there have been major technical and economic difficulties in harnessing the vast resources of the pre-salt, maintaining the status quo where Brazil is remains dependent of natural gas imports from Bolivia (CNI, 2016). In any case, the pre-salt event prompted the Bolivian state-owned YPFB to have uncertainties regarding Brazilian intentions to renew in 2019.

The recent dramatic reduction in Petrobras' international performance in the region is already visible, for example, in the renewal of the gas agreement. Thus, Petrobras could stop being a player in the purchase and distribution and, therefore, in guaranteeing the price, so it would be up to Bolivia to negotiate directly with a number of private companies. The immediate result of this new scenario is the following binomial: (i) lower price; and (ii) short-term contracts.

Considering recent challenges and opportunities regarding natural gas, and based on the 2017 Yearbook Energy Statistics, the country started operating the Incahuasi Plant, in the Municipality of Lagunillas, Department of Santa Cruz, which will inject approximately 7 Mm^3/d of natural gas. This implies an increase of 12% in the national production of this type of energy; thus, the gas supply in the domestic market and the export commitments would be guaranteed. Government authorities informed that with the Incahuasi Plant, a total of 104 Mm^3/d of processing capacity is reached throughout the country. The construction of this megafield demanded an investment of more than US$ 1,000 million.

Additionally, the Rio Grande LNG Plant was inaugurated, aimed at supplying natural gas to 27 cities in the departments of Beni, La Paz, Oruro, Pando, Potosí and Santa Cruz. The plant will send LNG in cryogenic tanks to the Regasification Satellite Stations, where the energy goes back to gaseous state and is delivered to the distribution networks of homes, shops, industries and service stations for vehicular natural gas (VNG). The LNG project has the construction of the Natural Gas Liquefaction Plant, a Virtual Transport System (cisterns) and Satellites Regasification Stations in each of the 27 cities where gas will reach. This system will contribute to the development of populations where conventional gas pipelines do not arrive at and will promote the use of natural gas, allowing the gradual substitution of LPG and gasoline consumption. The plant is expected to process 12 Mpcd of natural gas and produce 210 metric tons per day of liquefied natural gas.

In addition to the expansion of natural gas production and the inauguration of the LNG plant, and similarly to the case of Peru, the construction of a binational hydroelectric plant on the Madeira River was hampered at the beginning of the last decade by the lack of a clearing campaign and convincing public about its benefits[107] (BIATO, 2016). Similar resistance and mistrust prevented further attempts to resume the project in 2007. Nevertheless, as previously stated, the country intends to become the region's 'exporter of electricity and has dense dialogues with Brazil aimed at jointly exploiting the potential in the Amazon region.

It is worth mentioning the Andean Electrical Interconnection System (SINEA)[108], a project that arises from the desire to achieve a regional interconnection between countries that make up the Andean Community (Colombia, Ecuador, Peru and Bolivia, as well as Chile as a country associated to that entity). The aim is to create a general community framework that allows integration in the energy market between the countries mentioned. However, in a first stage Bolivia will participate only as an observer country. SINEA aims to develop an Andean Electricity Corridor, creating an interconnected electrical system between 2014 and 2024. Its planning is developed by the Technical Group of Planning Agencies of the electricity sectors of the member countries of the Andean Community and Chile (GOPLAN) and its regulation is within the Working Group of Electricity Regulatory Organizations of the Andean Community and Chile (GTOR)[109].

Moreover, it is worth mentioning the construction of 50 MWp photovoltaic solar power plant Oruro, which will guarantee the supply of electricity for the National Interconnected System (NIS). ENDE Matriz is the executing company and the project is financed by the Central Bank of Bolivia (BCB), the French Development Agency (AFD) and the

[107] Besides, there was nationalist and preservationist resistance in Bolivia, as well as reluctance of Brazilian investors to prioritize the construction of the Cachuela Esperanza plant, located exclusively in Bolivian territory.
[108] See: http://www20.iadb.org/intal/catalogo/PE/CM%202015/15821.pdf. It should be noted that the Galapagos Declaration (2011) creates the Council of Ministers of SINEA. See **Appendix E**.
[109] See: https://www.enernews.com/media/briefs/integracion-electrica-regional-retos-y-perspectivas_2016.pdf.

European Union (EU). The start date of the project was 2016, with the forecast of completion in December 2018[110].

It should be noted the failure of the Lliquimuni block, located in the north of the department of La Paz, which covers an area of 156km^2. The government had reported since 2011 that the block contained 50 million barrels of oil (50 MMbbl) and one trillion cubic feet of gas (1 TCF), according to preliminary results of a seismic exploration study conducted by YPFB Petroandina. However, the operations of the exploratory drilling project culminated with the discovery of 'non-commercial' hydrocarbon volumes, although full exploration has required more than US$ 500 million. Despite the failure, YPFB announced that plans to drill a second hydrocarbon well in Lliquimuni.

Another failure was the construction of the dams in the Madeira River basin. The initial proposal was to build four plants in the region: two in the Brazilian territory (Jirau, 3,750 MW, and Santo Antonio, 3,568 MW), one in Bolivia (Cachuela Esperanza, 990 MW) and one binational (Guajará-Mirim[111], 3.000 MW), all run-of-river HPP. However, the agenda was postponed for more than a decade, due to the erosion of bilateral relations, especially since the nationalization of Petrobras refineries in 2006. As a result, Brazil has built the two in its national territory, but plans for two others were on paper.

It also should be highlighted that the location of these projects facilitates the incorporation of new energy into the Brazilian integrated grid. For Bolivia, it becomes an absolute priority agenda, since gas exports to Brazil (reason why there was Bolivian economic growth in the last decade) are threatened by the drop in gas prices and the depletion of Bolivian proven reserves. By the way, it should be noted that energy integration for Bolivia represents a vector of national development.

3.3 Brazil

The Federative Republic of Brazil is the largest country in the South American subcontinent, both in territorial extension (8.5 million km^2) and in population (207.7 million inhabitants). Due to its size, the country has noticeable regional differences and

[110] See: http://www.ende.bo/NewProyectos/resena/proyecto--const.-generacion-solar-de-oruro-fase-i.
[111] It will stabilize the Jirau reservoir, adding 280 average MW.

has a high median income level, therefore its GDP per capita at current prices is US$ 8,648.05.

In Brazil, the Ministry of Mines and Energy (MME) is responsible for the electricity sector[112]. Policies and guidelines are in the hands of the Presidency of the Republic, the National Congress, the National Council of Energy Policy (CNPE) and the MME itself. The regulation and supervision are up to the National Electric Energy Agency (Aneel)[113]. State and municipal regulations are controlled by the Brazilian Association of Regulatory Agencies (ABAR).

The National System Operator (ONS) manages the wholesale electrical market. Accession and monitoring (national and municipal governments) is the responsibility of the National Energy Policy Council (CNPE), the Power Sector Monitoring Committee (CMSE), the Energy Efficiency Management Committee (CGEE) and the Electric Energy Secretariat (SSE/MME).

Regarding electricity generation, there are private and state-owned utilities, Eletrobras[114] and Itaipu Binacional (Br-Py). Regarding the transmission, there are private and state companies, as well as in generation. There is the National Interconnected System (SIN), subdivided into N, NE, S, SE/CO Subsystems (and isolated systems), Eletrobras, Transmission Services Agreement (CPST), Contract of Use of the Transmission Systems (CUST), Transmission System Connection Agreements (CCT) and Facilities Sharing Agreements (CCI). The Brazilian electricity generation and transmission system is a large hydro-thermo-eolic system, with a predominance of hydroelectric power plants and with multiple owners.[115]

The distribution is the responsibility of the Brazilian Association of Electric Energy Distributors (ABRADEE), Other Transmission Facilities (DIT) and Eletrobras. The Electric Energy Trading Chamber (CCEE) and Eletrobras (majority shareholder's

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[112] It is worth mentioning that, as in the case of other countries, other ministries and institutions can also play an important role depending on the matter. As an example, we have the Ministry of Environment (MMA), Ministry of Science, Technology, Innovation and Communications (MCTIC), including the Federal Revenue of Brazil (RFB).
[113] Depending on the matter, the National Agency for Oil, Gas and Biofuels (ANP), the Ministry of the Environment (MMA), the National Water Agency (ANA) and the National Environment Council (CONAMA) also play a fundamental role.
[114] The company's role in the Brazilian internationalization in the region is emphasized through investments in neighboring countries, although the effort has translated into a slow and marginal change of scenario.
[115] See: http://www.ons.org.br/pt/paginas/sobre-o-sin/o-que-e-o-sin.

delegation) carry out the commercialization. There is a Regulated Contracting Environment (ACR), the Free Contracting Environment (ACL), as well as Energy Trading Contract in Regulated Environment (CCEAR). Studies and planning of the energy sector are the responsibility of the Energy Research Company (EPE) and the Oil, Natural Gas and Biofuels Secretariat (SPG/MME).

The MME is also the responsible ministry for the hydrocarbon sector. The policies and guidelines of the sector are controlled by the Presidency of the Republic, the National Congress, the National Energy Policy Council (CNPE), as well as the MME itself. The regulation and supervision are in the hands of the National Agency of Petroleum, Natural Gas and Biofuels (ANP), environmental inspection agencies and the Federal Revenue of Brazil (FRB). Concerning the exploration and production (E&P), Petrobras, International Oil Companies (IOCs) and independent actors, supply industry to the oil sector, and companies of the O&G value chain are the responsible entities. Petrobras and private companies provide refining and transportation, while the commercialization is up to traders, Petrobras and *Pre-Sal Petróleo S.A.* (PPSA)[116].

Figure 11 presents the Brazilian summarized energy balance in 2015. Primary supply (285,226.90 ktoe) is composed of crude oil (104,552.00 ktoe, 36.7%), other primaries (90,964.46 ktoe, 31.9%), natural gas (39,028.90 ktoe, 13.7%), hydropower (30,853.72 ktoe, 10.8%), coal (16,006.70 ktoe, 5.6%) and nuclear (3,821.18 ktoe, 1.3%). In final consumption (232,537.06 ktoe), transport (83,773.75 ktoe, 36.0%), industrial (81,213.58 ktoe, 34.9%), and residential consumers (24,943.13 ktoe, 10.7%) stand out, being 18.2% supplied by electricity. In Mercosur, Brazil corresponds to 60.2% of total primary supply and 66.3% of final consumption. Regarding supply, 14.9% is of crude oil, 41.4% natural gas and 82.6% coal, 5.6% of electricity are imported and 0.04% are exported, 30.2% of crude oil production are exported.

[116] In the Brazilian case, Eletrobras plays an essencial role in electricity sector while Petrobras in the O&G sector.

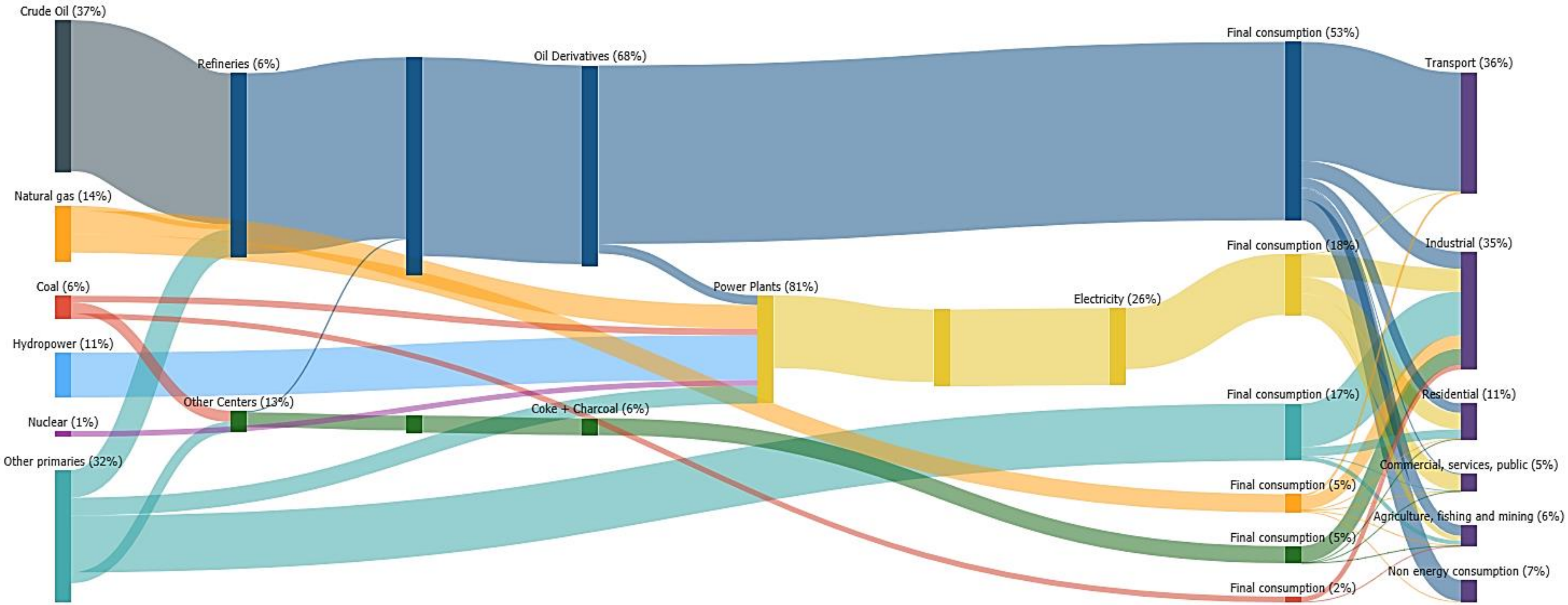

Figure 11. Brazilian summarized energy balance (2015, in ktoe)

Source: sieLAC-OLADE.

As already presented, its electricity sector is characterized by being divided into four subsystems (North, Northeast, Southeast/Central-West and South) that interconnected make up the National Integrated System (NIS). There is an installed capacity of 142,003 MW and hydroelectric power represents 64.9% of it. The important role of the thermal park (18.4%) and the nuclear power plants located in Angra do Reis (1.4%) are also highlighted. Concerning Non-Conventional Renewable Energies (NCRE), Brazil leads in terms of installed capacity in the region, which is 21,699 MW and is composed of biomass, wind, solar and wave.

Among the main policies in the Brazilian electricity sector, the following ones can be mentioned: (i) energy efficiency (rational use of existing energy resources); (ii) affordable tariff; (iii) tariff equity (to redress the uneven concentration of the negative effects of tariff subsidies between regions); (iv) generation expansion (demand growth); (v) diversification of the electricity matrix (reduction of hydrological risk); (vi) increased participation of renewable sources (mitigation of emissions). It is worth mentioning that the first auction of alternative sources took place in 2007, with small hydroelectric power plants (SHPs) and biomass predominating. Since 2008, in reserve energy auctions biomass, SHPs, wind (since 2009) and solar (since 2014) tend to stand out.

Among the policies that promote energy efficiency, the following draws attention: (i) special credit lines; (ii) Labeling Programs (Procel); and (iii) Research and Development (R&D) programs. Policies that promote affordable tariff are: (i) regulation by incentives in the distribution segment; (ii) merit-order dispatch; and (iii) tariff flags. Regarding tariff equity, the sectoral fund of the Energy Development Account (CDE) of the states can be highlighted, which has been incorporated into the policies of Brazilian electricity sector (BES) since 2013.

With regard to generation expansion, it is important to mention (i) the tariff recognition of over-contracting by electric power distributors; (ii) centralized auctions; (iii) BNDES financing lines; and (iv) the Special Regime for Incentives for Infrastructure Development (REIDI). Regarding the diversification of the electricity matrix, it focuses on (i) distributed generation; (ii) increasing natural gas generation; and (ii) incentives for energy generation coming from domestic coal. Finally, regarding the increase in the participation of renewable sources, we can mention (i) the Alternative Energy Sources Incentive Program (PROINFA); (ii) discounts on the use tariffs of distribution and transmission systems for consumers and generators that negotiate energy from the incentivized sources; and (iii) reserve power auctions and auctions from alternative sources.

According to 2017 OLADE Energy Statistics Yearbook, in terms of electricity, Belo Monte hydroelectric plant was inaugurated in the municipality of Altamira (southwest of Pará). Built on the Xingu River, the plant is the largest HPP in the country, the third largest in the world (installed capacity of 11,233.1 MW)[117] and its energy is already available for the National Interconnected System[118].

As presented in section 3.2, the Jirau HPP was also inaugurated, on the Madeira River, composed of 50 turbines, with an installed capacity of 3,750 MW and an assured power of 2,279.40 MW (currently, it is the third largest hydraulic generation plant in Brazil and the 17th in the world). Jirau generates under the concept of run-of-river, so it does not need a large reservoir to operate, which reduces environmental impacts associated to the project. On the other hand, Santo Antônio hydroelectric plant advances and will have a total of 50 turbines and an installed capacity of 3,568 MW[119].

The wind generation was the one that presented a more significant expansion, with a growth of 43.2% between November 2015 and the same month in 2016[120]. In the same period there was also expansion of solar (8.4%), hydraulic (6.4%) and thermal (4.0%) sources. The advance of renewable sources goes in the same direction of the commitment assumed by Brazil during COP 21, of raising at least 23% to the share of renewable energies in the electricity matrix until 2030.

Still according to the 2017 Energy Statistics Yearbook, Brazil launched the RenovaBio initiative, aimed at expanding the participation of renewable fuels in a way compatible with market growth and in harmony with the international commitments assumed within the framework of COP 21. Likewise, the Chapada do Piauí Wind Power Complex was

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[117] With assured guarantee of 4,571 thousand average MW (MWmed), it is a run-of-river HPP. This means that the generation will vary according to the amount of water of the Xingu River in each period of the year. See: http://www2.aneel.gov.br/aplicacoes/hotsite_beloMonte/index.cfm?p=7.

[118] The commercial operation of the second generating unit with an installed capacity of more than 611.11 MW was initiated. The liberated unit is part of the 18 generating units that will be completed and operated gradually until 2019.

[119] See: http://ri.santoantonioenergia.com.br/santoantonioenergia/web/conteudo_pt.asp?idioma=0&conta=28&tipo=50139.

[120] It is worth mentioning the generation of direct and indirect jobs related to this industry (REN 21, 2016).

inaugurated in Brazil, it is made up of three wind farms, with installed capacities of 205 MW, 172.4 MW, and 59.2 MW. Consequently, as a result of the measures to stimulate the generation of energy by the consumers themselves (micro and mini distributed generation), Aneel registered 7,610 distributed generation connections, totaling an installed power of 73,569 kW. Among the most used renewable energies, the solar photovoltaic source stands out, with 7,528 connections.

Regarding energy efficiency policies, in June 2016 the incandescent lamps left the market in Brazil. The rule applies to the import and commercialization of incandescent lamps for general use in Brazilian territory. In addition, prohibition of selling incandescent lamps in the country helps stimulate the adoption of efficient, more economical and durable options, such as LED.

With these advances, Brazil ranked 2nd in hydraulic power capacity (behind China)[121], 4th in wind energy capacity (behind China, EUA and Alemanha, respectively), 3rd in solar water heating capacity (behind China and Turquia), 2nd in biodiesel/ethanol production[122] (behind USA in both cases). This data is presented in the Renewables 2016 Global Status Report (REN 21, 2016).

It is important to highlight the role of the private sector in these cases. Within Latin America and the Caribbean (LAC) region, the highest private participation in infrastructure (PPI) investment was driven by Brazil[123]. The top market for PPI investment in 2016 was Brazil, where US$14.2 billion in investment in the energy sector accounted for 93% of the total transaction volume of US$15.2 billion (World Bank Group, 2016).

Concerning binational ventures, Brazil participates in GASBOL (see subsection 3.2) and in Itaipu Binacional (to be detailed in subsection 3.4). Regarding international electricity

[121] Brazil has 8.6% of the world's hydraulic capacity in 2015, behind China (27.9%).
[122] 24% of global biofuel production in 2015, begind the USA (46%).
[123] Investment in infrastructure with private participation in Emerging Markets and Developing Economies (EMDEs) fell sharply in 2016. US$71.5 billion committed across 242 projects in 2016 represents a 37 percent decline in investment compared to 2015 and a 41 percent decline compared to the annual average of US$121.4 billion over 2011 to 2015. The number of infrastructure projects with private participation in EMDEs also declined substantially. The 242 projects recorded in 2016 is 27% lower than the number of projects in 2015, which had 334 projects reach financial closure, and 57% lower than the annual average of 421 projects per year over 2011–2015 (World Bank Group, 2016).

trade, Brazil has interconnection agreements[124] with Argentina: Rincón S.M. (Ar) – Garabí (Br), of 2,200 MW (greater capacity and in force since the beginning of the last decade) and P. de los Libres (Ar) – Uruguayana (Br), of 50 MW; Paraguay: Itaipu energy of 14,000 MW, and Foz de Iguazú (Br) – Acaray (Py), of 50 MW; with Uruguay: Livramento (Br) – Rivera (Uy), 70 MW; and with Venezuela: Boa Vista (Br) – El Guri (Ve), of 200 MW, not integrated into the interconnected system[125]. In fact, the exchanges that take place between Brazil and its neighbors are largely due to pre-established binational agreements such as that of the Itaipu binational power plant (see section 2.3). There are also exchanges that respond to contracts between private or surplus energy, the latter targeting the spot market (COCIER, 2016, 2017a).

Figure 12 shows Brazilian energy trade for both exports and imports in 2014. When it comes to exports, crude oil to USA (US$ 1,296 m; 28.9%), China (US$ 1,197m; 26.7%), India (US$ 741m; 16.5%) and Chile (US$ 648m; 14.4%) stands out, as well as biofuels and waste to Japan (US$ 41m; 82.0%). When it comes to imports, crude oil from Nigeria (US$ 1,897m; 87.4%), Algeria (US$ 168m; 7.7%) and Colombia (US$ 51m; 2.3%) stands out, as well as gas from Bolivia (US$ 920m; 69.9%), Spain (US$ 92m; 7.0%) and Norway (US$ 90m; 6.8%), coal from USA (US$ 219m; 32%) and Colombia (US$ 126m; 18.5%), oil products from the USA (US$ 294m; 77.4%), and electricity from Paraguay (US$ 413m; 100.0%).

[124] Regarding interconnection, the Brazilian regulation allows international interconnections to be included in the country's high voltage system (SIN), which is remunerated by all generators and consumers through annual fixed payments, known as 'tariffs for use of transmission system' (TUST).
[125] In this case, it makes room for understanding the role for international interconnections in (Brazilian) regions like this outside the National Interconnected System (NIS).

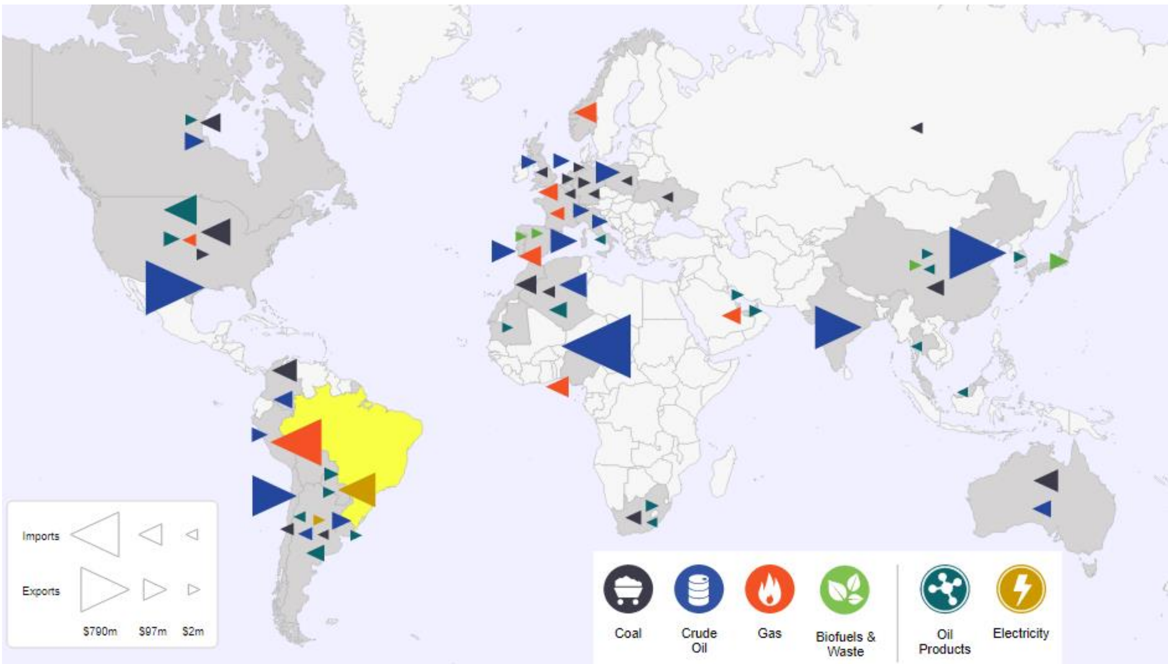

Figure 12. Brazilian energy trade, both exports and imports (2014, in 2000 US$)

Source: IADB Energy Database based on UN COMTRADE.

Regarding the hydrocarbon sector, it is important to emphasize that for the first time in history the country ended a year with a surplus in the oil account, with a positive result of US$ 410 million in 2016. To encourage investments in the hydrocarbon sector, guidelines for the 14th bidding round of blocks for oil and natural gas exploitation were approved, for the 2nd round of pre-salt block auctions and for the 4th bidding round for marginal fields. Moreover, Brazil broke record production of natural gas and reached 111.1 Mm^3/day, which represents an increase of 18% in comparison with November 2015. The total production of oil and natural gas in November was approximately 3.307 Mbep/day. In turn, oil production totaled 2.609 Mbbl/day, an increase of 9.6% in relation to the same month in 2015. The Lula field, in the Santos Basin, was the largest producer of oil and natural gas, producing, on average, 663.2 kbbl/day of oil and 29.2 Mm^3/day of natural gas. The volume of oil was the largest produced in a single field, surpassing the previous record reached in September 2016, when Lula produced 639,700 bbl/día (OLADE, 2017).

Considering the recent challenges and opportunities, the *Arco Norte* Project, designed by Eletrobras, aims to build an approximately 1,800 km transmission line involving Brazil, Guyana, Suriname and French Guiana[126]. During the Rio+20 (2012) meetings, it was recognized as an important contribution to the Latin America and the Caribbean (LAC) SE4ALL initiative, whose goal is to end energy poverty in the region. In 2013, the IDB approved funding of US$ 1.9 million. Between 2014 and 2015, the baseline study (already concluded), the pre-feasibility study, and the public consultation of identified alternatives were carried out. It is worth highlighting the difference between the countries of the region in terms of average generation costs (US$/MWh), since those of Guyana and Suriname are higher than the long-term Brazilian marginal cost (US$ 56/MWh)[127]. See **Appendix D**.

Among the challenges that lie ahead, Brazil will face difficulties concerning the integration of large quantities of variable generation, mainly due to the lack of storage capacity of new hydroelectric plants. However, in the LAC region there are very good examples of integration of large amounts of non-conventional renewable energy (NCRE) and non-manageable, like Nicaragua, Honduras, Costa Rica, Chile and Uruguay among others, what contributed to break some myths. Among them, four stand out: (i) NCREs could only have a small participation because they were of poor quality; (ii) NCREs are very expensive and require subsidies; (iii) sudden variations in production make NCREs ungovernable (this would be only true if they were concentrated in a single point); (iv) the NCRE require a thermal backup of the same magnitude as their power to cover them in case they could not produce (however, in the sites where a large percentage of NCRE penetration was reached, there is a drastic reduction of thermal backup needs and a large synergy between classical hydroelectric power station and the NCRE with regard to the firm power) (CIER, 2016b).

Finally, another major challenge to the Brazilian electricity sector is the privatization of Eletrobras. On January 19, 2018, the Planalto Palace released a bill with rules for privatization. The government expects the privatization to increase the cash of the National Treasury in 2018, raising about R$ 12.2 billion (around US$ 4 billions). Today, the Brazilian Union holds 51% of the common stock (with voting rights) and a 40.99% stake in Eletrobras' total capital. The government

[126] The initiative needs a conversion system, since the frequency in French Guiana is 60Hz and in other countries it is 50Hz. The national companies participating in the project are the Guyana Energy Agency (GEA), company of Guyana; *N. V. Energiebedrijven Suriname* (EBS), company of Suriname; *Electricité de France* S.A (EDF), company of French Guiana; Brazilian Electric Power Company S.A. (Eletrobras), agency of Brazil.
[127] See: http://www.kas.de/wf/doc/kas_20056-1442-5-30.pdf?160825232459.

also proposes a corporate restructuring to keep Eletronuclear and Itaipu Binacional, both subsidiaries of Eletrobras, under control of the Union, so that they remain outside the State's privatization process. Currently, the company is responsible for 70,201 km of transmission lines (47% of the national total).

In the case of Brazil, we concluded that new binational hydroelectric plants and/or international interconnections could avoid the dispatch of thermal power plants, which now have social (tariff increase) and environmental effects (emission increase). In addition, the difficulty in approving new reservoir hydroelectric plants in the country has led Brazil to finance and push the construction of (bi)national plants in other neighboring countries or to demand regional agreements submitted to the particularities of the Brazilian model. This behavior, to a certain extent, reinforces that regional integration has served national objectives, making room for questioning the country's role in this process. The Peruvian Amazon dam (Inambari) and the Bolivian Amazon dam (Cachuela Esperanza and Guajará-Mirim) represent cases in which the Brazilian role has been questioned through strong popular repression.

3.4 Paraguay

Paraguay has 6.7 million inhabitants and is located in the central region of the subcontinent. It has a territorial extension of 406.7 thousand km^2 divided into two large regions by the Paraguay River. They have different geology and topography. Agricultural products are its main exports, among which soybean stands out in first place and with more than 40%. The GDP per capita at current prices is US$ 4,089.55 and therefore Paraguay can be placed within the segment of low middle-income countries.

In Paraguay, the Vice Ministry of Mines and Energy (VMME), within the Ministry of Public Works and Communications (MOPC), is the ministry responsible for the electricity sector. The policies and guidelines of the electricity sector are up to the National Energy Board, the Energy Resources Directorate of VMME and the National Electricity Administration (ANDE). The regulation and supervision are in the hands of ANDE, the National Council of Public Companies (CNEP), the National Council of the Environment (CONAM) and the Secretariat of the Environment (SEAM). There is no electricity wholesale market in the country.

ANDE, Itaipu (14,000 MW equally shared with Brazil), Yacyretá (3,200 MW equally shared with Argentina) and Acaray (210 MW) are responsible for the electricity generation. With regard to transmission and distribution, ANDE is the responsable actor in the National Interconnected System (NIS), subdivided into Eastern, Central, South, North, West and Metropolitan Systems. Thus, ANDE constitutes a monopoly of generation, transmission and distribution (excluding the case of binational plants). There is no commercialization of electricity; in fact, there are special conditions for some large consumers, included in the Decree N. 2,109/1994[128], for the installation of large consumers connected at 220 kV and 66 kV levels, and the Decree N. 12,507/2001[129], which establishes the supply conditions for a future cellulose processing plant in the south of the country. The Energy Resources Department is responsible for the studies and planning of the sector.

Regarding the hydrocarbon sector, it is the responsibility of the Vice Ministry of Mines and Energy, within the MOPC, and the Ministry of Industry and Commerce (MIC), which deal with industry policies and guidelines, as well as regulation and supervision. Regarding exploration and production (E&P), *Petróleos Paraguayos S.A.* (Petropar) and several private companies are the responsible players. The transportation is with Petropar, while the commercialization is up to Petrobras, ESSO, COPETROL, Barcos y Rodado, PUMA, GAS CORONA, HIPASA, SUGAS, Lima Gas, Gas del Este, Yacyretá, Acaray Gas, COPESA, Petrogas and Norte Gas.

Figure 13 presents the Paraguayan summarized energy balance in 2015. Primary supply (8,333.84 ktoe) is based on hydropower (5,297.83 ktoe, 63.5%), other primaries (3,036.01 ktoe, 36.4%) and (imported) coal (3.47 ktoe, 0.04%). In final consumption (4.956,46 ktoe), transport (1,892.24 ktoe, 38.2%), residential (1,336.59 ktoe, 27.0%) and industrial consumers (1,336.53 ktoe, 27.0%) stand out, being 18.4% supplied by electricity. In Mercosur, Paraguay corresponds only to 1.8% of primary supply and 1.4% of final consumption. 73.8% of electricity are exported and 100% of coal are imported.

[128] See: http://www.leyes.com.py/todas_disposiciones/1994/decretos/decreto_2109_94.php.
[129] See: http://www.leyes.com.py/todas_disposiciones/2001/decretos/decreto_12507_01.php.

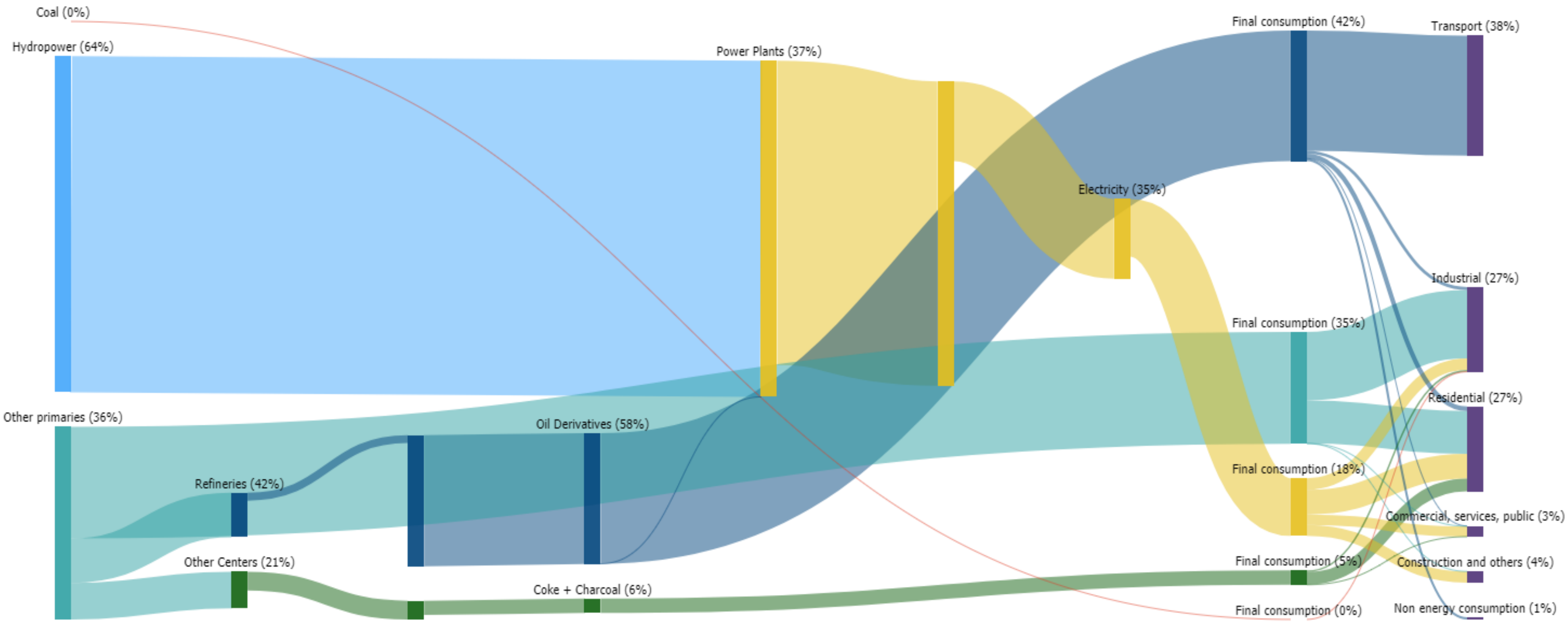

Figure 13. Paraguayan summarized energy balance (2015, in ktoe)

Source: sieLAC-OLADE.

Its electricity sector is characterized by having an installed hydroelectric capacity of 8,810 MW, which exceeds its energy needs by a large margin, placing Paraguay as a net exporter within the region.[130]. This capacity comes from its two binational power stations Itaipu and Yacyretá. In addition, there is a small thermal park that has an installed capacity of 24 MW.

According to 2017 OLADE Energy Statistics Yearbook, for the first time in the history of the 32 years of operation of Itaipu Binacional, the production of the plant exceeded the 43 MWh mark in the five-month period in which the binational contributed with 43,053 GWh to the electricity sector in Paraguay and Brazil.[131] Additionally, the value of the adjustment factor to be incorporated in the rate of repayment of the energy generated by the Itaipu hydroelectric plant for 2017 was defined. The value as of 2017 was US$ 1.8836/kW, which represents a reduction of 24% in relation to the one included in the 2016 tariff. In 2016, Itaipu Binacional produced a total of 103,098.37 GWh, a new world record in annual generation.

Defeated in the Triple Alliance War, the country created a long-term strategic partnership with Brazil in what concerns the production of hydroelectric energy. Itaipu Binacional (Py-Br) was created in 1974 as an international company to exploit the Paraná River's hydroelectric potential. The plant generates foreign exchange for Paraguay's economic and social development while allowing Brazil to own one of the world's most renewable power plants, contributing 11% to Brazil's electricity generation (BIATO, 2016).

The first generating unit of the project came into operation in 1984, having reached full operation of the 20 turbines in 2007 (14,000 MW of installed capacity). With no sluice, the Paraguayan side is represented by the National Electricity Administration (ANDE) and the Brazilian side by Eletrobras. However, it is noted that the negotiations between Brazil and Paraguay for the exploitation of hydroelectricity on the border come from the 1950s[132]. The base document for the project was the Treaty of Itaipu [133], signed in 1973,

[130] The country is a small consumer and a major exporter of energy, just like Bolivia.
[131] This generated energy would be enough to supply Brazil for 30 days and a city of São Paulo for a year and a half.
[132] The studies on the energy utilization of the region of *Sete Quedas* began in 1956, but during the presidencies of Jânio Quadros (January-August 1961) and João Goulart (1961-1964), these researches have grown (ESPÓSITO, 2012).
[133] See: https://www.itaipu.gov.br/sites/default/files/u13/tratadoitaipu.pdf.

which established the terms and regulations that are in force until the year 2022 (RODRIGUES, 2012a).

Half of the energy generated is generated for both countries, but Paraguay does not consume its whole share. Thus, in accordance with the Itaipu Treaty, the country can only 'sell' ('*ceder*' under the terms of the treaty) the surplus not consumed to Brazil, what has been questioned several times by Paraguay[134] (SANTOS *et al*., 2014, SANTOS *et al*., 2013). According to the Itaipu Treaty, in Art. XIII, 'energy produced by hydroelectric development (...) shall be divided equally between the two countries, each of which shall be entitled to acquire, as provided for Article XIV, of energy that is not used by the other country for its own consumption'.

In 2005, compensation to Paraguay for energy destined for Brazil increased. In 2007, the countries signed a memorandum of understanding on the company's debt with Eletrobras (OXILIA, 2009; RODRIGUES, 2009a). In 2009, the signing of the Joint Declaration 'Building a New Stage in Bilateral Relations' by Presidents Lula and Lugo raises the level of bilateral relations, establishing a series of historical decisions: (i) multiply by three the value of the factor of correction paid by Brazil as compensation for the surplus of Itaipu energy not used by Paraguay; and (ii) determine the construction of a 500 kV electric transmission line of 348 km, the first of high voltage, transporting the generated energy to Asunción then offering basic conditions for industrial development. The understanding raises from US$ 120 million to US$ 360 million the amount received for the energy transferred to Brazil. The transmission line (Itaipu - Villa Hayes) was financed by Brazil through unilateral and voluntary obligatory contributions to the Mercosur Structural Convergence Fund (FOCEM)[135] of US$ 550 millions[136] (CERQUEIRA CÉSAR, 2015, PARLASUR, 2013).

In fact, the project includes the 500 KV transmission line from Itaipu until the station of Villa Hayes (near the city of Asunción) and the extension of the station of Villa Hayes (500/220 KV transmission line). This additional transmission capacity allows Paraguay

[134] When Brazil imports energy from Paraguay, there is a need to pay royalties and the amount associated with the energy transfer ('*cedida*'). As an alternative, the inclusion of the hydrographic basin as a criterion for the distribution of royalties will promote more efficient water resource management, since the payment will be distributed throughout the basin of the plant (LORENZON *et al*., 2017).
[135] The FOCEM will be detailed in section 4.1.
[136] It should be noted that the transmission line was completed in 2013 and is in operation. See: http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=860.

to increase the exchange of energy with Argentina through the 220 kV interconnection between the towns of Clorinda (Ar) and Guarambaré (Py). The transmission line covers an approximate distance of 348 km.

With Itaipu, Brazil ensured a safe and profitable source of power to feed a production park in expansion, thus currently representing around 17% of the national consumption. On the other hand, Paraguay ensured access to financial resources with every condition to promote the structural transformation of its economy along with the availability of cheap power (BIATO *et al*., 2016).

As stated before, it is worth noting that the sale of electricity to neighboring countries has been one of the three pillars of the Paraguayan economy over the last thirty years (CERQUEIRA CÉSAR, 2015). However, the construction of Itaipu was not followed by the expansion of the electricity distribution infrastructure, missing the opportunity to channel this resource for the promotion of industrialization (CODAS, 2009, MASI, 2011). The use in the industrial sector[137] of the electricity of Itaipu and Yacyreta could supply industries that generate up to 2 million new direct jobs, since there is the potential to install around 465 thousand manufacturing industries that could generate that important number of jobs in the country (GISE, 2017).

In view of this scenario, that are two challenges that come up: (i) by the structure of the Treaty, the market for energy surplus not consumed by Paraguay has a monopsony characteristic; and (ii) risk of Paraguay suffering from Dutch disease[138], given that no extra income is being invested in the country on a long-term logic (infrastructure, job creation, industry, health and education, for example). Two natural endpoints for the dam are: (i) expirantion of the Teaty in 2023; and (ii) in some decades the dam is going to be disassembled.

In 2023, the treaty expires and the plant will be fully paid, that is, the debt of its construction will be completely paid off. This includes the Paraguayan half, so there is no longer the need for the country to amortize it with the sale of energy to Brazil. Paraguay will then be free to commercialize its energy surplus from the 50% that it owns from the

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[137] Investment in the industrial sector development is the best alternative for the hydropower surplus use under the analyzed conditions (BLANCO *et al*., 2017).

[138] Many claim the same risk for the case of Venezuela (oil) and Bolivia (NG). See: http://www.imf.org/external/pubs/ft/fandd/basics/dutch.htm.

generation of Itaipu as it sees fit. After 2023, each country will own half of the entire power produced at a cost of around US$ 4/MWh.

Notwithstanding, it is unclear what will happen after 2023[139]. In terms of price, it will depend, first, on how the regional macroeconomic framework goes. In the coming years, due to the economic crisis, much more energy will enter the Brazilian electrical system than current demand requires. Secondly, it will depend on the existence of alternative markets that can compete with Brazil with Paraguay's energy supply. As a way to pressure Brazil, Paraguay regularly (falsely) claims the right to sell primarily to third parties (Argentina and Uruguay), but the reality is that there is no legal possibility for this (according to the Treaty), neither based on transmission infrastructure nor on demand. In principle, one can believe that Paraguay must continue for several years to sell to Brazil, even though there are few alternatives as long as the Paraguayan domestic demand does not match its full amount. Thirdly, it will depend on the other sources of energy in the Brazilian market, especially the increasing entry of alternative sources of renewable energy (mainly wind and solar), as well as the 'commoditization' (and consequent reduction) of natural gas at world scale. Finally, it will depend on the type of contract. Brazil will be interested in a long-term contract, with a guarantee of supply, which will also impact the price.

Still on the price issue, it could lower about 66%, a portion that goes to pay the amount of the loans. Undoubtedly, this is not the interest of Paraguay, which already argues that the current value is low and therefore need to be maintained. With respect to the destination of this amount, (i) it could be split equally between Paraguay and Brazil, so that each one could use it in the way it best suits; or (ii) create a development fund (for the construction of other binational or regional power plants for the electrical/technological development of the two countries). This fund could serve as a means to deal with the technological update of the plant, that will reach 50 years of operation in about 15 years. It is believed, however, that most will be left to both countries to develop their infrastructure.

[139] In the case of Brazil, it will depend on whether the country will prioritize a cost containment policy to help keeping inflation under control or whether it will opt for a cash strategy for the company. On the Paraguayan side, a competitive pricing strategy tends to prevail in order to continue attracting electro-intensive industries to the country, especially in Brazil.

Although Paraguay has already informed that it will demand the totality of its energy until 2023, it is believed that the country should continue without consuming it for at least 10 years. With Paraguay's growth, Itaipu's growing demand for electricity in recent years will continue. However, as already highlighted, part of the 50 Hz Itaipu energy is transported to a converter station, the Ibiúna substation[140] (São Paulo), through a transmission system with capacity of 6,300 MW. In case of total consumption, the converter station will be idle. Then, it could serve as a communication source between Brazil and other countries in the region with frequency of 50Hz (for example, Argentina, Uruguay and Bolivia), corresponding to a very important regional communication channel that generates and transmits energy at 50Hz or 60Hz.

It should be noted that Itaipu represents about 17% of the electricity in Brazil, that is, security in the energy supply. On the other hand, for Paraguay, hydroelectric power is a political (national sovereignty[141]) and economic (source of foreign exchange) issue, just like oil for Venezuela. Thus, there will be two ways to manage Itaipu post-2023: (i) the most remote possibility of dividing the plant into two generating units, which would require changes in its constituent treaty; and (ii) maintaining binational administration.

Generally, the exchanges that take place between Paraguay and its neighbors respond largely to pre-established agreements such as the binational power stations of Itaipu and Yacyretá. To compensate for the lack of regulatory framework, all the exchanges made to date have been regulated by bilateral contracts (COCIER, 2016). Regarding international interconnections, Paraguay is interconnected with Argentina through two lines: El Dorado (Ar) – Carlos Lopez (Py) line, which has a capacity of 30 MW, the Clorinda (Ar) – Guarambaré (Py) line, which has a 90MW capacity and has been in existence since 1995. It is interconnected to Brazil through Foz de Iguazú (Br) – Acaray (Py), with capacity of 50 MW. In addition, it shares a connection through its two binational power plants, Yacyretá (3,200 MW) and Itaipu (14,000 MW) (COCIER, 2017a).

[140] The station is considered to be the world's largest high voltage direct current converter.
[141] The environmental and social losses with the construction of Itaipu were immense. However, the greatest damage was moral and political, since it strengthened the dictatorship of Alfredo Stroessner and threatened the country's energy sovereignty (CANESE, 2011).

Figure 14 shows Paraguayan energy trade, both exports and imports (2014, in 2000 US$). When it comes to exports, electricity to Argentina (US$ 84m; 100.0%) stands out, as well as biofuels and waste to Germany (US$ 4m; 80.0%) and UK (US$ 1m; 20.0%). When it comes to imports, oil products from Argentina (US$ 5m; 41.7%), Bolivia (US$ 4m; 33.3%) and Brazil (US$ 2m; 16.7%) stand out.[142]

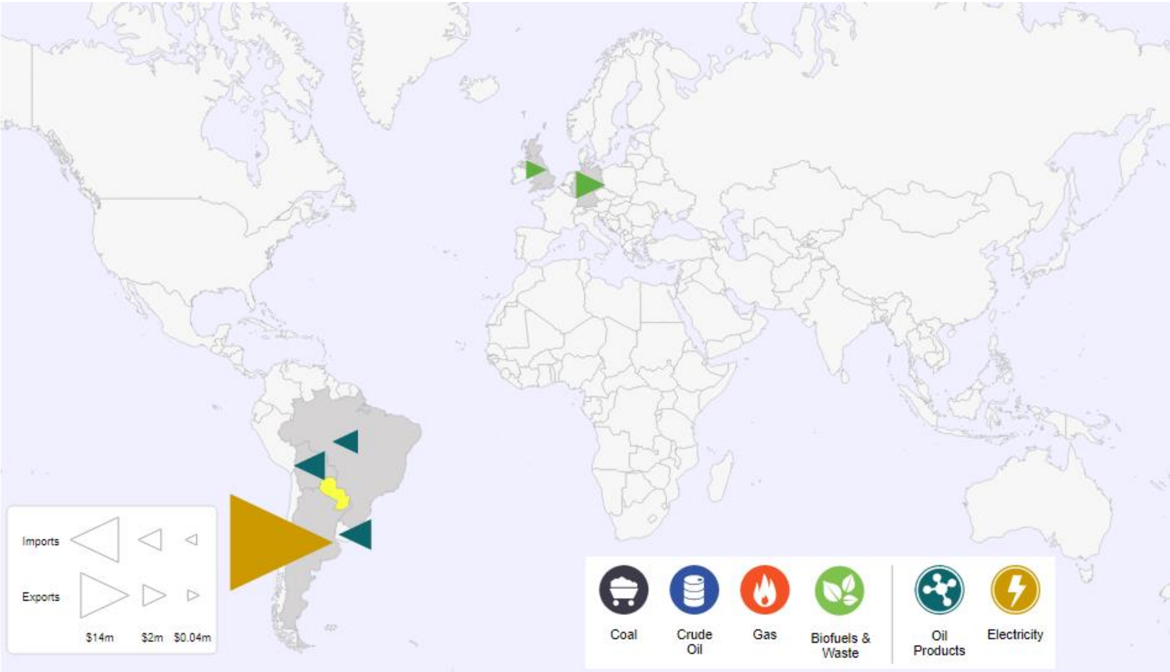

Figure 14. Paraguayan energy trade, both exports and imports (2014, in 2000 US$)

Source: IADB Energy Database based on UN COMTRADE.

According to the 2017 OLADE Energy Statistics Yearbook, Paraguay implemented the redefinition of prices and quality of common diesel by means of Decree N. 4.562/2015[143] that establishes new technical specifications for import and commercialization of petroleum products in the country. With these new specifications, the quality of diesel marketed in the country arises, a fuel that represents 63% of the total oil derivatives consumed nationwide. On the other hand, it was announced the discovery of traces of hydrocarbons in geological witnesses (rocks) of Pozo Jaguareté I (San Pedro), samples

[142] In **Figure 14**, it is worth noting that Brazil does not appear as an importer of electricity. This is probably due to the methodology of the IADB Energy Database and the nature of the Itaipu Treaty.
[143] See: http://www.leyes.com.py/todas_disposiciones/2015/decretos/decreto_4562_15.php.

taken from a depth of 2,600 meters. The government authorities suggest that with these new indications of hydrocarbons it can be deduced that there is a generating basin, which will give a closer approximation to perhaps the commercial discovery in the future. With these evidences, it will be possible to determine at how the generation of hydrocarbons is doing, so that the following perforations can be carried out in different places, but with a greater certainty of how the subsoil behaves.

It is essencial to detail the briefly presented transmission line 500 kv (Itaipu – Asunción – Yacyretá)[144], which belongs to the Integration Priority Projects Agenda (API) of IIRSA-COSIPLAN[145] in the Capricorn Axis[146]. This structured project is composed of two individual projects that are transmission lines: (i) 500 kV transmission line (Itaipu – Villa Hayes); and (ii) 500 kV transmission line (Yacyretá – Villa Hayes). The first one has already been presented and was already concluded in 2013. On the other hand, the second one proposes to improve the quality of the service and the reliability of the supply correcting the low voltage of the system, allowing to reduce the high technical losses of transmission (10% in peak hours). The transmission lines are currently operating at more than 70% capacity and the transformers are used almost to the limit of their power. The total amount of both projects is US$ 852 million.

The 500 kV transmission line Yacyretá (Ayola) – Villa Hayes has 362.9 km, total cost of US$ 297 million and is also an IIRSA-COSIPLAN API. As stated, it aims to improve the quality of the service and the reliability of the supply by correcting the low voltage of the system. As already informed, the station of Villa Hayes already exists. The second line is currently in execution and is scheduled to be completed in May 2018.

In addition to these two projects for the extension of transmission lines, there are no new binational power plant projects except for the expansion of Yacyretá (Ar-Py), in particular the Aña Cuá branch[147], which will require an investment of US$ 610 millions (own resources). The expansion project has an installed capacity of 270 MW (9.0% increase in current capacity), with three Kaplan turbines of 90.2 MW unit power and will enter full service at 48 months from the beginning of its construction. The average annual

[144] In this way, the two transmission lines will interconnect Itaipu with Yacyretá through the substation of Villa Hayes, since May 2018.
[145] See section 4.2.
[146] See: http://www.iirsa.org/proyectos/detalle_proyecto.aspx?h=317.
[147] See: http://www.yacyreta.org.ar/images/nm/licitaciones/670/PRESENTACION-COMPLETA.PDF.

generation is 2,000 GWh and the term of execution of the works is estimated at 50 months, from the signing of the contract. From the social point of view, there are no families to resettle and the work will demand directly and indirectly occupation of around 3,000 people.[148] Also, it is worth noting that 60% of the investments needed to generate in the Aña Cua branch are already made (dam, landfill and access). Considering the recent challenges, the already mentioned dilemma about Annex III of the Treaty of Itaipu after 2023 stands out. Besides that, it is worth mentioning that the following paradox has been consolidated: despite the large electricity generation and the fact that the country is the main exporter of hydroelectric energy in the world, (i) its energy matrix is still very unsustainable, since about 48% of total domestic consumption still comes from biomass, about 37% of oil and only about 15% of the electric power itself (CERQUEIRA CÉSAR and ARCE, 2014); (ii) Paraguay still has one of the lowest rates of electricity consumption in Latin America. (BLANCO *et al*., 2017); and (iii), the country suffered regular blackouts in Asunción, which led to the belief that Itaipu served mostly or exclusively Brazilian interests (BIATO, 2016).

Due to these problems and challenges, the country can take a reactive stance on the promotion of regional energy integration and on its position in the negotiations of Itaipu post-2023, since they deal with issues that touch on national sovereignty. Therefore, and considering the need of sustainable development and addressing climate change, it is crucial that the country revises its energy matrix. As noted, although it is one of the leading exporters of clean and sustainable energy in the region, its domestic consumption is still heavily based on non-renewable energy and therefore contributing negatively to CO_2 emissions.

As stated, the attractiveness of Paraguay lies in its reduced production costs and the pragmatism of its regulatory environment. In relation to Brazil and Argentina, it has low electricity costs, low tax rates, a simplified tax system, availability and flexibility of labor regime, lower wage costs, as well as facilities for obtaining licenses and registrations. Its geographical proximity to the main industrial parks and consumer markets in Brazil tends to reduce the time and cost of transportation.

In Paraguay, more than in other countries, energy is synonymous of national sovereignty. Itaipu (14,000 MW) and Yacyretá (3,200 MW) are specific examples of successful

[148] See: http://www.eby.org.ar/images/nm/Proyecto_Aa_Cua.pdf.

regional energy integration, although limited to binational initiative. Regarding Itaipu, there is a great deal of uncertainty about its post-2023 future, but it is believed that the operational status quo will be maintained: Brazil will remain the only country to be able to consume the portion not consumed by Paraguay for at least a decade, although this value will fall over time. As for Yacyretá, there are several projects that aim to increase the installed capacity of the plant, in addition to projects in progress to connect it to Itaipu.

3.5 Uruguay

Uruguay is a country of 3.4 million inhabitants located in the southeastern region of the South American subcontinent. It limits to the Northeast with Brazil, to the West with Argentina, and has coasts both in the Atlantic Ocean and in the Río de la Plata. Its GDP per capita at current prices is US$ 15,411.76, which places Uruguay as one of the high-income countries in the region according to the World Bank classification. The agricultural and livestock sector is of great importance in the national economy, although services and tourism account for a high percentage of GDP, with the latter becoming increasingly important.

In Uruguay, the Ministry of Industry, Energy and Mining (MIEM) is responsible for the electric and hydrocarbon sectors. The National Energy Directorate (DNE-MIEM) is in charge of defining the policies and guidelines of the energy sector, as well as promoting studies and planning. Regulation and supervision are up to the Regulatory Unit of Services of Energy and Water (URSEA). There are no State or municipal regulatory agents and the Electric Market Administration (ADME) manages the wholesale electric market.

With regard to electricity generation, there are private and state-owned companies, such as UTE (state-owned company) and private power generators, in particular wind power and thermal power generation with industrial waste biomass. Transmission and distribution are also in the hands of the UTE, and public and private companies operate in the commercialization. During IntegraCIER[149], UTE affirmed that the Uruguayan energy policy established the vision of energy independence in a context of regional integration, with environmental sustainability and in response to economic development,

[149] Ibero-American Energy Congress, held in November 2014.

towards a productive country with social justice (CIER, 2016b). Focusing on regional energy integration, the question is how far it is possible to reconcile energy independence with regional energy integration, since the latter leads to greater interdependence with neighboring countries.

In hydrocarbon sector, policies, guidelines and regulation are the responsibility of URSEA. Regarding exploration and production (E&P), the National Administration of Fuels, Alcohols and Portland Cement (ANCAP) in association with international private companies (Total, BP, BG, TULLOW Oil, Petrel-Schuepbach, YPF, for example) are the responsible companies. Refining and transportation are left to Petrobras Uruguay (NG distribution, lubricants, production and commercialization of fuels), in association with ANCAP, while the commercialization is controlled by ANCAP DUCSA.

Figure 15 presents the Uruguayan summarized energy balance in 2015. Primary supply (5,046.11 ktoe) is composed of other primaries (2,263.80 ktoe, 44.9%), (imported) crude oil (1,920.10 ktoe, 38.1%), hydropower (814.11 ktoe, 16.1%), (imported) natural gas (45.80 ktoe, 0.9%) and (imported) coal (2.30 ktoe, 0.05%). In final consumption (4.479,32 ktoe), industrial (1,852.94 ktoe, 41.4%), transport (1,235.20 ktoe, 27.6%) and residential consumers (796.35 ktoe, 17.8%) stand out, being 20.2% supplied by electricity. In Mercosur, Uruguay corresponds only to 1.1% of primary supply and 1.3% of final consumption. 100.0% of crude oil, natural gas and coal are imported. Besides, 9.6% of generated electricity are exported and 0.02% is imported.

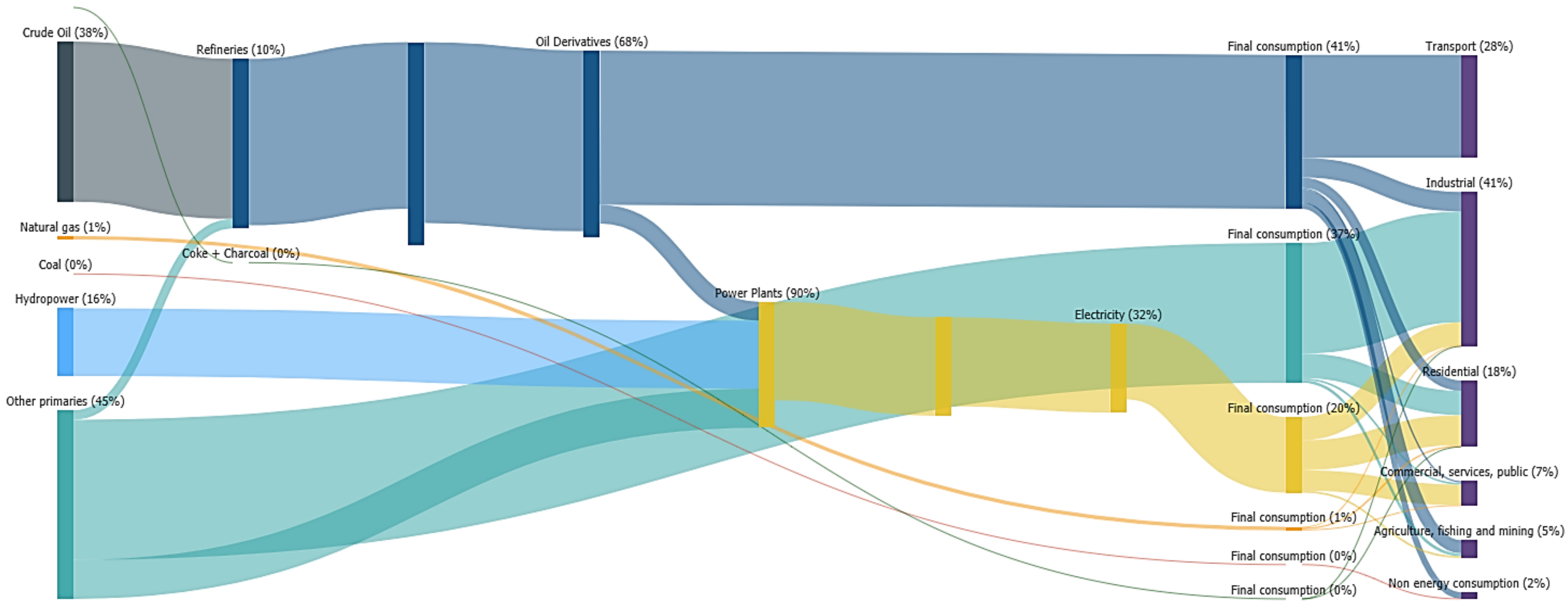

Figure 15. Uruguayan summarized energy balance (2015, in ktoe)

Source: sieLAC-OLADE.

Its electricity sector has an installed capacity of 3,723 MW, the largest percentage coming from hydroelectric sources (41.3%), followed by conventional thermal (31.6%) and then renewable energy (27.1%). Although there has been a notable development in the generation from wind and biomass sources during the last years, the production of electricity is strongly correlated with the hydrological conditions of the year.

According to 2017 OLADE Energy Statistics Yearbook, the country launched a benefit that will allow electrointensive industrial companies that maintain or increase their production to obtain a discount of up to 30% in the monthly invoicing of the electric power charge (without VAT). Additionally, in the First Electric Mobility Exhibition (MUEVE), the existing opportunities to acquire taxis and electric vehicles were presented. The plan also includes financial and infrastructure support for the first vehicles of this type. Besides, the Electric Vehicle Power Systems Network (SAVE) was launched, which will be extended in its first phase from Colonia to Chuy, passing through Montevideo, while in its second phase it will cover all routes.

It should be noted that the country completed four consecutive years (since October 2012) without commercial electricity imports, although Uruguay used to be dependent on imports from neighboring countries (Argentina and Brazil). This is a consequence of the "guidelines" implemented by the Uruguayan Government since 2005 with the objective of arriving at an "energy independence with diversification of the matrix with renewable and indigenous sources", according to MIEM. In fact, between 2014 and 2016, 28 wind farms have been inaugurated with an installed capacity of 1,212 MW. The biomass exceeded in 2016 for the first time the oil and its derivatives in the participation of the energy matrix, breaking a historical series of 52 years. Since 2008 biomass began to have greater participation in the generation of electricity and biofuels, being able to triple its value in 8 years.

2015 was the first year in which Uruguay exported energy significantly through UTE. Of the 11.5 TWh generated in the country, 1 TWh (8.7%) was exported by UTE. In 2016, for the first time, a private company sold energy abroad.

Uruguay launched a stimulus tool to strengthen public policy guidelines focused on the promotion of renewable energies through the participation of private investors. The Areaflin S.A., currently owned by UTE, opened its capital to the market by issuing shares to small savers who can be co-owners in the society of Valentines wind farm.

Participation to those who wish to invest larger amounts was also allowed. In this way, UTE has participated in the development of 34% of the wind farms in Uruguay (OLADE, 2017).

In recent years, Uruguay has incorporated renewable energy[150] to its energy matrix and recently agreed with Argentina on the sale of its shedding wind. Thanks to the growth in the exchange between both countries, this agreement has been achieved that benefits both nations to market the surpluses of their wind production (CIER, 2017c). In addition, the country signed two memorandum of understanding with China, in the areas of renewable energy and industrial cooperation. The goals are focused on the development of issues of common interest for both countries, which support the diversification of energy sources tending to promote economic development socially and environmentally sustainable (OLADE, 2017).

With regard to binational projects, the country is the joint owner of Salto Grande with Argentina, whose installed capacity is 1,890 MW[151]. In terms of international electricity trade, Uruguay has interconnections with Argentina through an occasional trade agreement with two 500 kV cross-border transmission lines and the Salto Grande binational dam. With Brazil, since 2001 there is the Rivera (Uy) – Livramento (Br) interconnection and there is an agreement for the use of the frequency converter signed by UTE and Eletrobras. UTE has developed an interconnection project with Brazil, Presidente Médici (Br) – San Carlos (Uy), of 500 MW power operating since mid-2017 (COCIER, 2016, 2017a).

Figure 16 shows Uruguayan energy trade, both exports and imports (2014, in 2000 US$). When it comes to exports, biofuels and waste to Portugal (US$ 14m; 77.8%) and Spain (US$ 4m; 22.2%) stand out, as well as electricity to Argentina (US$ 9m; 100.0%). When it comes to imports, crude oil from Brazil (US$ 364m; 71.7%) and Nigeria (US$ 144m; 28.3%) stands out, as well as gas from Argentina (US$ 14m; 100.0%), and oil products from Brazil (US$ 5m; 41.7%), Argentina (US$ 4m; 33.3%), USA (US$ 2m; 16.7%) and Chile (US$ 1m; 8.3%).

[150] Uruguay was in 3rd place in the investment in electricity and renewable fuels per unit of GDP, behind Mauritania and Honduras, respectively (REN 21, 2016).
[151] See section 3.1.

Figure 16. Uruguayan energy trade, both exports and imports (2014, in 2000 US$)

Source: IADB Energy Database based on UN COMTRADE.

According to 2017 OLADE Energy Statistics Yearbook, regarding the hydrocarbon sector, Uruguay signed an agreement from which, with the consent of ANCAP, the company British Gas (BG) made a partial transfer of their rights (50%) in block 13 offshore, in favor of Total, Exxon and Statoil.[152] Government authorities define this act as a new step in the path of offshore exploitation. Additionally, a contract was signed whereby Total ExxonMobil, operator of block 14 of hydrocarbons exploitation in the Uruguayan maritime platform, gives 15% of the contract it has with Uruguay to Norwegian company Statoil.

From the geographical point of view, the country is isolated regionally, having borders only with Argentina and Brazil. It is precisely with these only two countries that Uruguay already has both international interconnections and binational HPP. The country has shown signs of focusing on the export of wind energy to Argentina.

[152] In this way, the hydrocarbon exploitation continues in block 13, with BG as operator and the other three companies as non-operators.

3.6 Venezuela

Venezuela has 31.6 million inhabitants and is located in the northern region of the South American subcontinent. The country borders Colombia, Brazil and Guyana, besides being close to the Caribbean Sea. Its economy is heavily dependent on the exploitation and export of oil, as well as the export of ores. Venezuela has in the USA, China, Colombia and Brazil its main trading partners in both exports and imports

Although Venezuela is one of the countries with the highest degree of electrification in Latin America, the electrification of isolated, indigenous and border communities has represented a challenge for the Venezuelan State due to the remoteness of these places. Bolivia and Brazil, for example, face the same problem, once both countries have isolated systems (IS).

In Venezuela, the Ministry of Popular Power for Electric Energy (MPPEE) is responsible for the electricicty sector and its regulation/supervision. The National Development Plan (*Plan de la Patria*) Law, Second Socialist Plan of Economic and Social Development of the Nation 2013-2019 is in charge of defining the policies and guidelines for the energy sector, as well as promoting studies and planning. Regarding municipalities, in the Organic Law on the Public Service of Electricity (LOSSEL, 2010), chapter III Art. 32, it is stated that among the attributions of the municipalities it is to support the Ministry of Popular Power with competence in matters of electricity, in the control of the quality of the electric service in the territories that correspond to its jurisdiction. In the country, there is no wholesale electricity market given the monopoly of the public National Electricity Corporation S. A. (Corpoelec)[153] in the generation, transmission, distribution and commercialization of electricity. The MPPEE, through the current Institutional Strategic Plan of the Ministry of Popular Power for Electric Power (2013-2019), is responsible for the studies and planning of the electric sector.

Considering private investments in LAC electricity sector between 1984 and 2011, Venezuela was the country where this amount was the lowest (US$ 142 million), being 92.9% in generation. The transmission sector did not have any private investment, as in most other countries in the region[154]. In 2010, the country had neither any private participation in the electricity sector nor in generation, transmission or distribution. This

[153] Corpoelec was created in 2007, when the sector was nationalized.
[154] Except Argentina, Bolivia, Brazil, Chile and Peru.

is due to the fact that Venezuela experienced a process of re-nationalizations in 2007 (BALZA *et al*., 2013).

Ministry of the Popular Power of Petroleum and Mining (MPetroMin) is responsible for hydrocarbons sector and its policies and guidelines are controlled by the current *Plan de la Patria* 2013-2017. Regulation is the responsibility of MPetroMin and the National Gas Entity (ENAGAS). Regarding exploration and production (&P), the role of *Petróleos de Venezuela*, S.A. (PDVSA) and other operators with a concession agreement stands out in the natural gas sector; concerning the oil sector, the PDVSA monopoly plays an important role, either autonomously or in association with other operators (mixed companies). Refining, transportation and commercialization are also up to PDVSA[155].

Figure 17 presents the Venezuelan summarized energy balance in 2015. Primary supply (82,045.26 ktoe) is based on natural gas (39,019.20 ktoe, 47.6%), crude oil (35,775.57 ktoe, 43.6%), hydropower (6,311.16 ktoe, 7.7%), coal (622.12 ktoe, 0.8%) and other primaries (317.21 ktoe, 0.4%). In final consumption (43,359.35 ktoe), industrial (17,593.51 ktoe, 40.6%), transport (17,223.52 ktoe, 39.7%) and residential consumers (5,429.17 ktoe, 12.5%) stand out, being 16.5% supplied by electricity. In Mercosur, Venezuela corresponds to 17.3% of primary supply and 12.4% of final consumption. 74.4% of crude oil production are exported, 0.2% of natural gas is imported and 0.8% of eletricity is exported.

[155] It is worth mentioning that according to the law, the activities of exploitation, production, storage and commercialization of natural gas can be made by the State or by private entities, whether national or foreign. Therefore, there is no legal imposition to have a monopoly on these activities in the O&G sector. In the case of petroleum, the law of 2001 allows the State to carry on the operations of the industry, allowing the participation of private persons through an association agreement, in which the State must keep more than 50% of the share capital. Despite this, in practice PDVSA is the monopoly company of the oil sector.

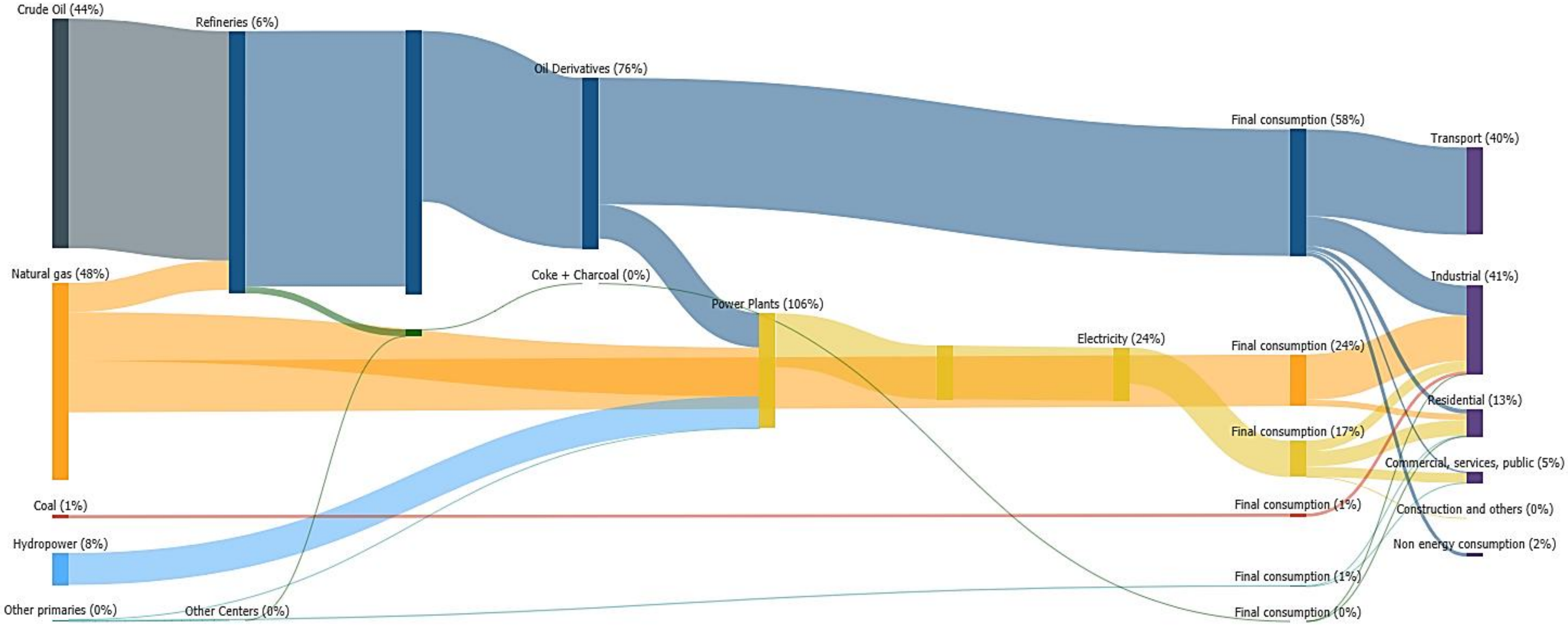

Figure 17. Venezuelan summarized energy balance (2015, in ktoe)

Source: sieLAC-OLADE.

Its electricity sector has an installed capacity of 31,037 MW, of which the highest percentage comes from non-renewable thermal (51.1%), followed by hydronergy[156] (48,8%) and then wind (1.6%). In terms of generation, 59.3% is hydro, 40.6% is non-renewable thermal, 0.06% is wind, and there has been an increase in the generation capacity of the National Electric System (SEN) in 489 MW, as : (i) entry into operation of unit 2 of the Fabricio Ojeda HPP - La Vueltosa (257 MW); (ii) Alfredo Salazar Plant (60 MW); (iii) entry into service of unit 2 of the Juan Bautista Arismendi gas plant (71 MW); and (iv) Táchira Plant (40 MW).

It is important to note that based on sieLAC-OLADE data, the electricity tariff in Venezuela (US$ 0.03/kWh) in 2015 is the lowest among Mercosur countries. Venezuela is followed by Argentina (US$ 0.04/kWh), Paraguay (US$ 0.07/kWh), Bolivia (US$ 0.11/kWh), Uruguay (US$ 0.17/kWh) and Brazil (US$ 0.17/kWh).

Regarding the Rational Use of Electric Power (UREE) in 2014, there was (i) installation of 10,410,195 energy saving light lamps, which allowed reducing demand by 251 MW, and benefiting 7,600,771 people in the 24 states of the country; (ii) launch of the *Plan Banda Verde* for residential users, as a measure of savings to reduce demand and cultivate the rational and efficient use of energy; (iii) completion of 24,122 information and awareness activities in communities and educational centers, in order to strengthen the energy saving campaign; and (iv) replacement of 13,448 air conditioning units with more efficient technologies. Since July 2016, Operation Cambalache began[157], which consists of the replacement of high-consumption air conditioners with new ones to contribute to rational and efficient use of electricity.

According to the official Corpoelec website[158], we can mention the following projects in operation: (i) wind measuring towers in El Anís and Chacopata; (ii) photovoltaic systems in isolated communities in Alta Guajira, Puerto Viejo, Cúpira and Guaruchar, Corioco and Chuao; (iii) hybrid systems in isolated communities in Los Roques; (iv) wind farms in La Guarija; (v) mini-hydroelectric plants in Piñango, Cuao, Wonken, Arautamerú, La Ciudadela, Kavabayén and Canaima; and (vi) solar heaters in Los Roques and La Orchila.

[156] One of these hydroelectric power plants, called Simón Bolivar (Guri), has 10,235 MW of installed capacity, representing more than 60% of all the hydroenergy used in the country. Besides, it is one of the largest HPP in the world.
[157] See: http://www.corpoelec.gob.ve/sites/default/files/informacion-cambalache.jpg.
[158] See: http://www.corpoelec.gob.ve/procesos-medulares.

In terms of international electricity trade, Venezuela has interconnections with Colombia: Cuestecita (Co) – Cuatricentenario (Ve), of 150 MW, Tibú (Co) – La Fría (Ve), of 80 MW, and San Mateo (Co) – El Corozo (Ve), of 150 MW. In addition, the country has an interconnection with Brazil, Boa Vista (Br) – El Guri (Ve), of 200 MW.

In the Second Socialist Plan for Economic and Social Development of the Nation 2013-2019[159], published in 2013, we can highlight the following targets: (i) build three Thermal Power Plant (TPP) with a total generation capacity of 2,100 MW, which will use petroleum coke generated by the process to improve crude oil in the Orinoco Oil Belt; (ii) strengthen the self-sufficiency electricity system in the operational fields, ensuring national elecitricity autonomy and flexible schemes for the generation of 1,260 MW; and (iii) expand and adapt the electric system in the western region, in the electric system in the central region, and in the eastern electric system. Among the electricity sector programs, we can emphasize: (i) the use of coke, gas, coal and liquids for thermal power generation; (ii) permanent monitoring structure, through operations centers and inter-institutional situational room; and (iii) the electricity sector's development and industrialization program. Among the policies of the hydrocarbon sector, the following stand out: (i) E&P of oil and gas; (ii) oil sovereignty; (iii) hydrocarbon transformation centers; (iv) energy matrix diversification; (v) industrialization of hydrocarbons; and (vi) conservation of the environment.

It is worth mentioning that in the Development Plan for the National Electric System 2013-2019 (PDSEN 2013-2019)[160] the goal of the installation of 149 hybrid wind-photovoltaic systems (including Apiapá) is established, however, since these competences were transferred to the Alternative Sources Management of Corpoelec, it was not further developed, being the last one installed by Fundelec in 2013.[161] The plan aims to develop 613MW of renewable energy for isolated and rural communities, of which 500 MW are wind-based. Other potential renewable resources include solar, small hydro, bagasse cogeneration and biogas. In addition, the plan seeks to electrify 2,512 off grid communities through solar PV and hybrid systems equivalent to 63MW.

[159] See: http://www.mppp.gob.ve/wp-content/uploads/2013/09/ley_plan_patria.pdf.
[160] See: http://www.mppee.gob.ve/download/publicaciones_varias/PDSEN%20web.pdf.
[161] See: https://www.evwind.com/2016/07/29/el-abandono-de-los-proyectos-de-energias-renovables-en-venezuela/.

Figure 18 shows Venezuelan energy trade, both exports and imports (2014, in 2000 US$). When it comes to exports, crude oil to USA (US$ 11,007m; 49.1%), India (US$ 5,443m; 24.3%), China (US$ 3,477m; 15.5%) and Spain (US$ 683m; 3.0%) stands out, as well as oil products to USA (US$ 74m; 33.2%), Brazil (US$ 59m; 26.5%) and Turkey (US$ 35m; 15.7%). When it comes to imports, crude oil from Algeria (US$ 45m; 100.0%) stands out, as well as oil products from USA (US$ 35m; 92.1%), Belgium (US$ 2m; 5.3%) and China (US$ 1m; 2.6%), gas from Colombia (US$ 102m; 100.0%), coal from Spain (US$ 7m; 53.8%) and Colombia (US$ 2m; 15.4%), and electricity from Colombia (US$ 37m; 100.0%).

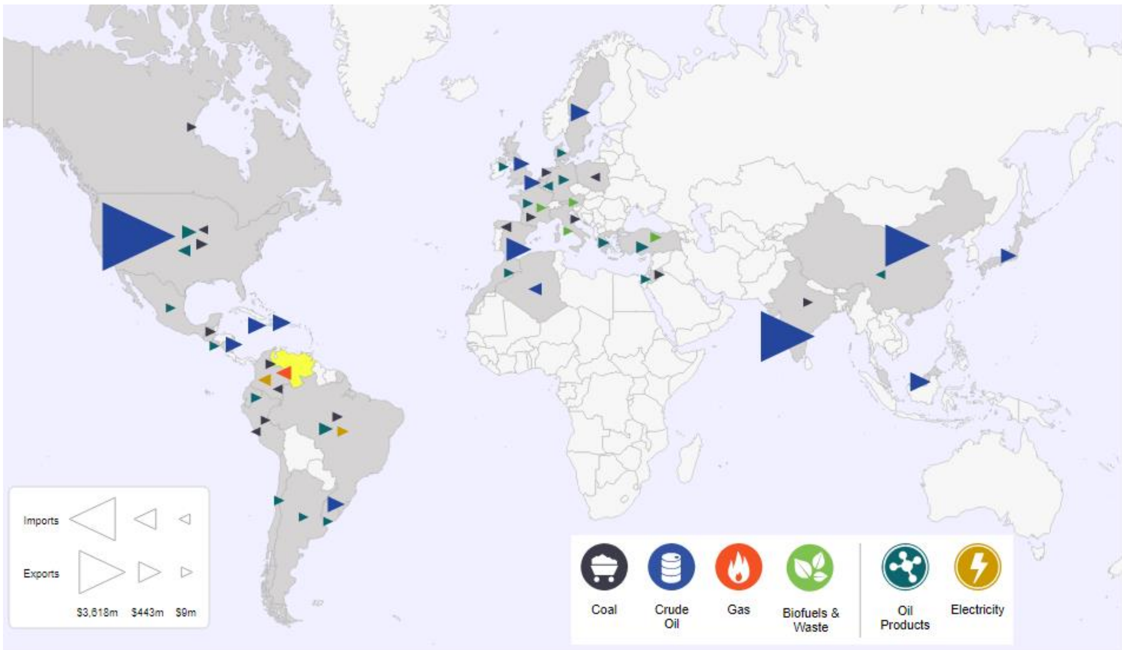

Figure 18. Venezuelan energy trade, both exports and imports (2014, in 2000 US$)

Source: IADB Energy Database based on UN COMTRADE.

Due to geographic proximity to the Brazilian isolated system, it is possible to think of strategies, international interconnections or perhaps binational projects between both countries. Despite the obstacles related to the Amazon region, it should be noted that some of these possibilities have already been considered by the Brazilian government.

Albeit in nominal terms, Venezuela has the largest gas reserves in LAC, but it is known that most of them correspond to associated gas. According to the Gas Regulatory Entity in Venezuela (ENAGAS), 70% of gas production is consumed by the oil activity itself, mainly for its re-injection into the oil fields. The lack of natural gas in the western part of Venezuela is one of the causes of the decline in oil production observed in that area. This has been one of the main reasons for the construction of the gas pipeline from Colombia (KOZULJ, 2008). Indeed, Venezeula has signed a memorandum for gas integration/interconnection with Colombia (July 2004), Colombia and Panama (July 2006), Colombia and Ecuador (October 2007)[162].

In terms of regional energy integration, the agreement that establishes the fundamental terms and conditions for the implementation and execution of the Natural Gas Supply Project from Venezuela to Trinidad and Tobago was signed in 2017, through a gas interconnection from the Field Dragon, in the northeast of Venezuela, to the Hibiscus Field, in Trinidad and Tobago[163].

It is important to note that Petrosur, Petrocaribe, Petroandina and Petroamerica initiatives are all Venezuelan-led organizations. Here, the relationship between foreign policy, diplomacy and energy played by the Venezuelan state company PDVSA is clear, what was already highlighted in this thesis (see subsection 2.1.3).

Petrosur is a political and commercial enabler promoted by the Bolivarian Republic of Venezuela and, with the support of Brazil, Argentina and Uruguay, establishes cooperation and integration mechanisms based on the complementarity of energy resources. Petrosur seeks to minimize the negative effects of the countries of the region in terms of energy payments, by reducing transaction costs (eliminating intermediation), access to preferential financing and taking advantage of commercial synergies to solve economic and social asymmetries. It was born in 1988 and it is a political platform for alignment with Mercosur (already in the context of the Venezuela separation from CAN).

Venezuela's stated goal with the **Petrocaribe** Agreement is to foster regional solidarity and alleviate financial hardship endured by countries in the Latin America-Caribbean

[162] See: http://colombia.embajada.gob.ve/index.php?option=com_content&view=article&id=6&Itemid=9&lang=es.
[163] See: http://www.pdvsa.com/index.php?option=com_content&view=article&id=6783:venezuela-exportara-gas-natural-a-la-republica-de-trinidad-y-tobago&catid=2&Itemid=101&lang=es.

region in face of rising oil prices. Signed in 2005[164], the Agreement vouches for the direct sale of petroleum products, but there are no price concessions, since Venezuela, as a member of OPEC, is obliged to sell its oil at market price.[165] Rather, Petrocaribe allows governments to pay for petroleum over time, so countries have up to 25 years to pay off oil bills or can provide goods and services in exchange for oil since President Hugo Chávez's administration.[166] However, the context of Venezuela's crisis has turned the numbers down significantly. The countries's quota has dropped dramatically and the Petrocaribe cutback is largely affecting Caribbean economies. In a scenario without Petrocaribe financing, the region will continue to require cooperation from other oil producers to face the rising challenges concerning energy security, since the cost of energy in the region is one of the biggest in the world with a high dependence on fossil fuels and a more limited access to alternative sources of electricity than most countries of Latin America (CANUTO, 2015). Therefore, it is clear that the initiative was strongly shaken by domestic factors within Venezuela, which corresponds to a relevant institutional barrier (see subsection 2.3.1).

The energy integration initiative **Petroandina** came to terms in 2005 in Lima (Peru), as a common platform or 'strategic alliance' of state oil and energy entities among Bolivia, Colombia, Ecuador, Peru and Venezuela, in order to promote electricity and gas interconnection, mutual provision of energy resources and joint investment in projects. In 2006, Bolivia and Venezuela announced the Petroandina creation, rising in 2007 as a mixed binational oil company.[167]

Venezuela also promotes the **Petroamérica** initiative in 2005, a proposal for energy integration of the peoples of the continent. Its roots come from the Bolivarian Alternative for the Peoples of Our America (ALBA) and are based on the principles of solidarity and complementarity between countries, as well as the fair and democratic use of resources for the development of their peoples. In another level of integration, the agreements framed in Petroamerica propose the integration of the state energy companies of Latin America and the Caribbean (LAC) to operationalize the agreements and make joint

[164] There are now 18 members of Petrocaribe: Antigua and Barbuda, Bahamas, Belize, Cuba, Dominica, Dominican Republic, Granada, Guatemala, Guyana, Haiti, Honduras, Jamaica, Nicaragua, Saint Kitts and Nevis, Saint Vincent and Grenadines, Saint Lucia, Suriname, and Venezuela.
[165] See: http://www.petrocaribe.bz/services-view/key-agreements/.
[166] See: https://www.as-coa.org/articles/explainer-what-petrocaribe.
[167] See: http://www.ilumina.org.br/criada-a-petroandina/.

investments in the exploitation and commercialization of oil and natural gas. The idea of Petroamerica is to consolidate the three previous initiatives (Petrocaribe, Petroandina and Petrosur). One of its chief project is the proposed Southern Gas Pipeline.

According to the 2017 OLADE Energy Statistics Yearbook, in terms of the hydrocarbon sector and in order to contribute to the balance of the global oil industry, the country announced the implementation of a cut of 95 kbbl/day, without undermining its international contractual commitments. The measure is framed, in compliance with the agreement of reduction of production reached between member nations and non-members of the Organization of the Petroleum Exporting Countries (OPEC), in 2016. The production of crude oil in September 2016 reached a positive variation close to 2,534 Mbbl/day, due to the growth of 17 Mbbl/day of the Orinoco Oil Belt. The increase in PDVSA's installed processing capacity in the Orinoco Oil Belt was also announced, through the start-up of oil treatment plants in the joint ventures Petrolera Sinovensa and Petrocarabobo. On the other hand, the increase in gas prices was officially announced in February 2016. The reduction of the subsidy of gasoline in Venezuela, in addition to honest fuel prices, seeks that users actually consume the octane required by their vehicles.

Through PDVSA Gas, Venezuela executed a natural gas conversion project for two turbogenerator units (TGU) of the Josefa Joaquina Sánchez Bastidas Complex, in the Vargas state. This project focus on advancing the change of the energy matrix for consumption of liquid fuels (diesel) by natural gas in the electricity sector and thereby stabilizing the national electricity system hit by the El Niño weather phenomenon, with clean and safe energy. Additionally, these actions allow the release of 14,620 barrels of liquid fuel per day, which, due to its high profitability in the international market, represents a significant foreign exchange income for the nation. Besides, with the activation of a new compression train at the 'Copa Macoya' plant, PDVSA added an additional 80 Mpc of gas to the domestic market, destined for thermogeneration and petrochemicals; thus allowing the replacement of diesel by gas in thermoelectric plants in the center of the country (OLADE, 2017).

Considering recent challenges and opportunities, it is worth noting that (i) the country has never fulfilled its promise to invest in the Abreu e Lima Refinery (RNEST); (ii) it did not go ahead with the famous 'Southern Gas Pipeline'; and (iii) although it has led the proposal for the creation of the Bank of the South, it has not advanced. In addition, the already presented Petrocaribe, Petroandina, Petrosur and Petroamerica did not advance fully in their objectives.

The **RNEST**[168] started operations in 2014 with the first set of units (Train I) and is located at the Suape Port Industrial Complex, 45 km from Recife, in Pernambuco (Brazil). It has a processing capacity of 230,000 bpd and its main objective is to produce diesel oil (70%) and to enable the demand for derivatives from the North and Northeast region to be met, with a reduction in imports. A pre-agreement with Venezuela foreseeing the guarantee of supply for this refinery has been closed but has not been implemented.

The **Great Southern Gas Pipeline**, also known as Venezuela-Argentina Gas Pipeline, would correspond to a major work of South American physical energy integration. The project would link Venezuelan reserves to the consuming centers of Brazil and Argentina (with possible branches to Bolivia and Uruguay), creating demand for Venezuelan gas and, in the medium term, solving the Argentine energy problem, which focus on gas and has reserves only for another ten years (PAZ and NUNES, 2011). Launched in December 2005 at the 29th Mercosur Summit in Montevideo (Uruguay), its construction was reaffirmed as the main work of the South American Energy Ring in April 2007, at the First South American Energy Summit held on the island of Margarita (Venezuela). With estimated costs of around US$ 20 billion, it should be the largest infrastructure integration project in South America, it was planned to start working in 2009 and then it would inaugurate the first stretches as early as 2013. However, the Great Gas Pipeline not even reached the initial operations (JAEGER, 2016).

The **Bank of the South** was proposed at the end of the last decade and presents a challenge in terms of regional financial integration. In 2014, the UNASUR foreign ministers decided to implement the *Banco do Sul* with an initial capital of US$ 7 billion, which would finance integration projects in South America[169]. The charter of Bank of the South was signed in 2009 by the Presidents of Argentina, Bolivia, Brazil, Ecuador, Paraguay, Uruguay and, Venezuela. Five countries have approved the document in their parliaments, but Brazil and Paraguay are still processing its approval (BARROS, 2016).

[168] Capable of processing the national heavy oil and imported oil from Venezuela.
[169] See: https://www.cartamaior.com.br/?/Editoria/Internacional/-Banco-do-Sul-outro-legado-de-Chavez/6/31014.

In the Venezuelan case, it is perceived that the macronomic problems of domestic and international natures strongly affected the daring plans to advance as an important player in the regional energy integration process. With initiatives involving countries throughout Latin America and the Caribbean, Venezuela's current scenario is that there are no concrete integration projects. Ergo, diesel gasoline is being imported and the national gas production is going down, without new investments.

Venezuela (as well as Uruguay) play(s) a marginal role in current regional electricity integration. Uruguay is somewhat geographically isolated between Argentina and Brazil, countries with which Uruguay already has binational (Salto Grande, with Argentina) and international interconnections such as Livramento - Rivera and Presidente Médici - San Carlos (both TL with Brazil). On the other hand, Venezuela is a politically and economically unstable country[170] due to its domestic vulnerability to the international crude oil price. In this way, crude oil is also protagonist in its regional insertion, playing an important role in successful initiatives (Petrosur, Petrocaribe, Petroandina and Petroamerica) and unsuccessful projects (RNEST, Southern Gas Pipeline and Bank of the South). We concluded that neither country is involved in major regional projects, being outside any energy integration scenarios.

In general, this chapter showed that regional energy integration projects have been at the mercy of the dichotomy between government policy and State policy, the macroeconomic (inter)national context, and the asymmetric weight that projects play for the different countries involved. Besides, institutional, regulatory and resource allocation structure between these countries is extremely diverse and, once again, asymmetric. Finally, it is also possible to realize the relative loss of participation of regional financing mechanisms, such as the IDB, CAF, FONPLATA, FOCEM and BNDES, in favor of China. From a geopolitical and geo-strategic point of view, this movement demands a prompt response from the countries of the region, either by the resumption of regional autonomy or by those who historically seek to represent regional leadership, as is the case of Brazil.

[170] It is worth recalling the already mentioned political context in which Venezuela enters Mercosur in the mid-2012. Since its accession, the country has been involved in political dilemmas and conflicts. In turn, this led to the temporary and definitive suspension of the Mercosur. Therefore, it becomes clear the relevance of political factors in this process, ratifying that regional energy integration is not an exclusively physical and technical matter, but has a multifaceted nature.

Despite the diversity of issues analyzed in each of the six countries, it is also important to consider (i) the difference between relative prices within and between countries; (ii) the nature of tax structures; (iii) the profile of macroeconomic policies; (iv) the dynamics of regulatory policies (energy and environmental sector); and (v) the lack of energy sector planning in most countries in the region. In addition, the need to deepen these issues in future studies is highlighted in order to fully map the complexity of the issue in detail.

4. Regional perspective

The purpose of this chapter is to add regional perspectives into the already presented national perspectives of the Mercosur countries. Here, we use regional qualitative primary sources such as norms, laws, international treaties, agreements, memorandum of understanding, regulatory frameworks, decisions, recommendations, decree, resolutions, framework agreements, declarations, programs and planning are emphasized.

The structure of the chapter is again divided into two main sections, which international organizations that cope with energy integration in the region: Mercosur (section 4.1) and UNASUR (section 4.2). Generally, the history, normative framework, legal and institutional bases of the region's energy integration will be presented, focusing on Mercosur and UNASUR cases.

4.1 Mercosur

Section 2.2 presented and analyzed Mercosur. Here, the focus is precisely the energy sector, highlighting (i) the institutional evolution of the matter within Mercosur; and (ii) the role of the Working Subgroup (SGT-9). In addition, there is a brief comparative analysis of recent energy policies with regard to policies to ensure energy security based on the six previous sections.

As already presented in section 2.3, it is important to point out that there are huge projects related to regional energy integration in the Mercosur region prior to the very creation of the same[171], especially in the 1970s and 1980s. The 1990s are characterized by the creation of international electrical interconnections, although the first one (Br-Uy) dates back to the 1960s.

Table 13 depicted the evolution of the energy institutional design within Mercosur. For this purpose, the official Mercosur database was used, considering 25 official regulations

[171] Such as the main binational hydroelectric projects Salto Grande (1979), Itaipu (1984) and Yacyretá (1994).

and documents dealing with *energy*, *electricity*, *oil*, *gas*, *biofuels* and *international interconnections*.

Table 13. Evolution of Mercosur's official energy institutional design (1993-2012)

Year	Document	Subject
1993	MERCOSUR/GMC/RES N. 57/93[172]	Defines guidelines of Energy Policies in Mercosur
1996	MERCOSUR/GMC/RES N. 150/96[173]	Deliberates on the negotiating guidelines for Sub-Working Group N. 9 'Energy'
1998	MERCOSUR/CMC/DEC N. 10/98[174]	Regulates electric exchanges and electrical integration in Mercosur
	MERCOSUR/GMC/RES N. 32/98[175]	Takes the project related to electrical interchanges and electrical integration to CMC
1999	MERCOSUR/CMC/DEC N. 10/99[176]	Promotes gas integration in Mercosur
2000	MERCOSUR/CMC/DEC N. 59/00[177]	Creates the Mining and Energy Sub-Working Group
	MERCOSUR/CMC/DEC N. 60/00[178]	Institutes the high government officials forum responsible for mining and energy issues in Mercosur
2001	MERCOSUR/GMC/RES N. 33/01[179]	Decides on the negotiating guidelines for Sub-Working Group N. 9 'Energy'

[172] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/1F59CE1DBE84885D0325821C00417FBB/$File/RES_057-1993_ES_Direc.Pol%C2%A1tic.Energ.en%20el%20Mercosur_Acta_03_93.pdf.
[173] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/DC522DD4A30D91D40325821C0043FE8C/$File/RES_150-1996_PT_PautaNegociaSGT%209%20-%20Energia.pdf.
[174] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/94EE66668FDE0BAC0325821C00444588/$File/DEC_010-1998_ES_Memorandum_Entend_Inter-El%E2%80%9Act-Integ-El%E2%80%9Actrica_Acta%20%201_98.pdf.
[175] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/462B920E29567CEA0325821C00445C26/$File/RES_032-1998_ES_Proyecto_Decisi%C2%A2n%20N%C2%A7%201a%2012-98_Acta%202_98.pdf.
[176] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/BF7BF0DFCFCCE83D0325821C00448089/$File/DEC_010-1999_ES_Memor-Interc-Gas%C2%A1feros%20e%20Integ-Gas%C2%A1fera_Acta%20%202_99.pdf.
[177] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/804F1F391973D2B90325821C0044B302/$File/DEC_059-2000_ES_Reestructuraci%C2%A2n_%C3%A0rg-Dep_GMC-CCM_Acta%202_00.pdf.
[178] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/F085C28C4D0C87D70325821C0044A6F5/$File/DEC_060-2000_ES_Reuni%C2%A2n%20Mtros_Minas-Energ%C2%A1a_Acta%202_00.pdf.
[179] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/6E4043127ED88AD50325821C0044C9F6/$File/RES_033-2001_ES_Pauta%20Neg-SGT%20N%C2%A7%209_Acta%203_01.pdf.

2002	MERCOSUR/GMC/RES N. 32/2002[180]	Mercosur Technical Regulation of reference diesel specifications for exhaust emissions test
2005	FRAMEWORK AGREEMENT ON ENERGY COOPERATION N. 19[181]	Proposes regional energy complementation between Mercosur States Parties and Associated States
	MERCOSUR/CMC/DEC N. 07/05[182]	Division of the Sub-Working Group of 'Energy and Mining' into two subgroups
2006	MERCOSUR/CMC/RES N. 02/06[183]	Unique scheme for the control of natural gas use as a vehicular fuel in Mercosur
	MERCOSUR/CMC/DEC N. 36/06[184]	Memorandum of understanding to establish a special Sub-Working Group on biofuels
2007	MERCOSUR/CMC/DEC N. 49/07[185]	Mercosur action plan for cooperation on biofuels and creation of Ad Hoc Group on Biofuels
2008	MERCOSUR/GMC/RES N. 36/08[186]	Mercosur technical regulation on minimum safety and energy efficiency requirements for household appliances that use gas as fuel
2009	MERCOSUR/GMC/REC N. 01/2009[187]	General guidelines for energy efficiency in the field of Mercosur
	MERCOSUR/GMC/REC N. 02/2009[188]	Guidelines for renewable energy sources in the Mercosur

[180] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/BE852B11DFCD397E0325821C00451AC0/$File/RES_032-2002_ES_FERR_RTM_Diesel_Emis_Gases_Acta%202_02.pdf.
[181] http://www.mercosur.int/msweb/portal%20intermediario/Normas/acordos%20es/44_05_ACUERDO%20MARCO%20COMPLEMT%20ENERGETICA%20MCS-EA_ES.pdf.
[182] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/60A121B3AC78D7450325821C00454D3F/$File/DEC_007-2005_ES_Divisi%C2%A2n%20SGT%20N%C2%A7%209.pdf.
[183] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/5AAD6A34BDD4D08C0325821C00457ECC/$File/RES_002-2006_ES_ControlGasNatural.pdf.
[184] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/DF5EA9534EC2D5E10325821C0048A9FF/$File/DEC_036-2006_ES_Memorandum%20Biocombustibles.pdf.
[185] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/2444DBE05DD213080325821C0048C55D/$File/DEC_049-2007_ES_Plan%20Accion%20Biocombustibles.pdf.
[186] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/B591578E286F25040325821C0045AC96/$File/RES_036-2008_ES_RTM%20GAS.pdf.
[187] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/80968C4EBDC14E7C0325821C0045D53A/$File/REC_001-2009_ES_Directrices%20Eficiencia%20Energetica.pdf.
[188] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/8B20C6C0951FDAB60325821C0045DAF8/$File/REC_002-2009_ES_Directrices%20Fuentes%20Renovables%20Energia.pdf.

	MERCOSUR/GMC/RES N. 04/2009[189]	Mercosur technical regulation on low voltage electrical cables and conductors
2010	MERCOSUR/GMC/RES N. 04/2010[190]	Mercosur technical regulation on switches for fixed electrical installations
	MERCOSUR/CMC/DEC N. 02/2010[191]	FOCEM project: 500 MW electric interconnection betweem Uruguay-Brazil
	MERCOSUR/CMC/DEC N. 03/2010[192]	FOCEM project: interconnection link in 132 kV between Iberá – Paso de los Libres Norte
	MERCOSUR/CMC/DEC N. 07/2010[193]	FOCEM project: implementation of the 500 kv system in Paraguay between Villa Hayes – Itaipu
	MERCOSUR/CMC/DEC N. 11/10[194]	FOCEM project: proposes the mapping of Mercosur's oil and gas production chain
2012	MERCOSUR/CMC/DEC N. 01/2012[195]	FOCEM project: interconnection link in 132 kV between Iberá – Paso de los Libres Norte

Source: Own elaboration based on Mercosur database; CMC = Common Market Council; GMC = Common Market Group; DEC = Decision; REC = Recommendation; RES = Resolution.

[189] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/315BDDC1F2BD9EB90325821C0045FA25/$File/RES_004_2009_ES_RTM-Cables%20y%20Cond%20Baja%20Tensi%C2%A2n.pdf.
[190] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/280DBC5CCEC30A0F0325821C00462748/$File/RES_004-2010_ES_Interruptores%20paraInstalaciones%20El%E2%80%9Actricas.pdf.
[191] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/F6867F9DDF05D55F0325821C00466B5C/$File/DEC_002-2010_ES_Apro%20Proy%20Inter%20El%E2%80%9Ac%20Uy-Br.pdf.
[192] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/0D7446B458E5DBE60325821C00514CB0/$File/DEC_003-2010_ES_Apro%20Proy%20Inter%20El%E2%80%9Ac%20Iber%C2%A0%20PdelosLibres.pdf.
[193] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/A2E3A44058091C070325821C0046570F/$File/DEC_007-2010_FERR_ES_Proyecto%20Itaipu.pdf.
[194] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/94BE018BB19D175D0325821C0046A026/$File/DEC_011-2010_ES_Proyecto%20Cadena%20Productiva%20Petroleo%20y%20Gas.pdf.
[195] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/4EC1911CB9FF9E7A0325821C0046DC0D/$File/DEC_001-2012_ES_Aprobaci%C2%A2n%20de%20recursos%20adicionales%20Proyecto%20%20Iber%C2%A0.pdf.

As shown, Mercosur member countries have reached agreements and memorandum on energy issues throughout the organization's existence, especially since the late 1990s. Five points will be highlighted below.

In the first Mercosur document that discusses the energy issue (**Resolution N. 57/1993**), Energy Policies in Mercosur are drawn. The document highlights: (i) favoring integration between the energy markets of the States Parties, with freedom of purchase and sale of energy companies and free transit of energy, respecting the laws in force in each country; (ii) promotion of rational use of energy and conservation; (iii) the admission of the possibility of binational or multilateral energy agreements within or outside the region; and (iv) the preparation of regional integrated energy planning studies in accordance with national macroeconomic planning. It is clear that already in the first document the binational character that will be present in the different agreements stands out.

The second point to be highlighted is that **Decision N. 10/1998** is a memorandum of understanding regarding electrical exchanges and electrical integration in Mercosur. There is therefore no forecast for the execution of energy transmission line projects and the construction of gas pipelines; that would require more action and investments from the Member States. Then, it is understood that the document, while pioneering the integration of electricity in Mercosur, aims to remove legal and political barriers to energy exchanges between members, not assuming the role of infrastructure expansion for the transport of energy, which is still precarious among Mercosur countries. The third point is that **Decision N. 10/1999** bears many similarities to Decision N. 10/1998, since the text itself appears to have been built upon it. The difference between them is that Decision N. 10/1998 addresses integration based on electricity while N. 10/1999 deals with gas exchanges and gas integration between Mercosur States Parties (PERGHER, 2016)[196].

The fourth point highlighted can be found in the **Framework Agreement on Energy Cooperation** (2005). In the document, there is an interest in 'advancing the integration of production and transportation', which would necessarily promote the expansion of energy transport infrastructure, as well as joint production among Mercosur countries (interactions already highlighted in section 2.2). However, the rest of Mercosur legislation

[196] Neither Decision N. 10/1998 nor Decision N. 10/1999 became positive law and were not incorporated into the domestic law of the respective countries. This is largely due to the intergovernmental nature of Mercosur, which departs from the supranational profile of certain institutions of the European Union (see section 2.2).

does not appear to be a normative basis for such interest, and there are only regulations on reducing national barriers to energy exchanges. In addition, as already emphasized in this thesis, the agreement points out great asymmetries in the sector between the Member States of the Agreement. In its Art. 6, it is highlighted the possibility of concluding regional, subregional or bilateral agreements in the areas of (i) commercial exchange of hydrocarbons; (ii) interconnection of the electric transmission networks; (iii) interconnection of pipeline networks and other hydrocarbon pipelines; (iv) cooperation in the exploration, exploitation, and industrialization of hydrocarbons; and (v) renewable energy sources and alternative energy sources.

The last point emphasized is that since 2012 there are no recommendations, directives, resolutions and/or decisions on the official Mercosur website. This will be presented with details in **Figure 19**.

With regard to the issue of the different projects to be developed within Mercosur, the Fund for the Structural Convergence of Mercosur (**FOCEM**), which is the first solidarity financing mechanism for the bloc countries and it aims to reduce the existing asymmetries within them. The creation of FOCEM took place with Decision CMC N. 45/2004[197]. In turn, Decision CMC N. 18/2005[198] established standards for its integration and operation, and CMC Decision N. 01/2010[199] defines its current regulation. More recently, Decision CMC N. 22/2015[200] gives continuity to the Fund.

Created at the end of 2004 and operating since 2006, the FOCEM is based on a system of contributions and distribution of resources in an inverse manner, which means that countries with greater relative economic development make greater contributions and, at the same time, countries with less relative economic development receive the greatest resources in order to finance their projects. The funds are intended for countries and

[197] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/449D95325EC237700325821C0050DA08/$File/DEC_045-2004_ES_FondoConvergenciaEstructural.pdf.
[198] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/893E41876CA26A6C0325821C00510E9F/$File/DEC_018-2005_ES_FE_IntyFuncFOCEMyFortalEstrctInstit.pdf.
[199] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/8695D844309A8FD30325821C005125D5/$File/DEC_001-2010_ES_FERR1_Reglamento%20FOCEM.pdf.
[200] See: http://gd.mercosur.int/SAM%5CGestDoc%5Cpubweb.nsf/B04D3A6F6B1156AF0325821C0054AAB3/$File/DEC_022-2015_ES_%20Renovacion%20FOCEM.pdf.

delivered as a non-refundable donation to finance up to 85% of the eligible value of the projects presented. Contributions to FOCEM began in 2006, considering a total annual amount up to 2012 of US$ 100 million. With the entry of Venezuela into Mercosur, and until 2015, the Fund reaches US$ 127 million annually. These resources are allocated to projects submitted by Mercosur States Parties with the criterion of benefiting the smaller and less developed economies.[201] Therefore, it is considered the central point of any regional integration process that is to reduce regional asymmetries. This logic of contributions and distribution of resources is presented in **Table 14**.

Table 14. Annual contributions and resources received in FOCEM

Country	**Annual contributions (US$ millions)**	**%**	**Annual resources received (US$ millions)**	**%**
Br	70	55.12	11.55	9.09
Ar	27	21.26	11.15	9.09
Ve	27	21.26	11.50	9.06
Uy	2	1.57	36.96	29.10
Py	1	0.79	55.44	43.65
Total	127	100.00	127.00	100.00

Source: MERCOSUR (2015).

Based on **Table 14**, it can be seen that Brazil is the country that contributes most to FOCEM (55.12%), while Paraguay has the least capital (0.79%). The contributions provided by Argentina (21.26%) and Venezuela (21.26%) are quite similar. As already explained, this logic is related to the GDP size of each country. Conversely, the annual resources received go mainly to Paraguay (44.65%) and Uruguay (29.10%). In addition, taking into account the distribution of funds by programs, it is noteworthy that 43% goes to the infrastructure sector.

It is also interesting to note the existence of a Sub-Working Group within Mercosur that specializes in energy issues (SGT-9). As presented in **Table 13**, it was created by Decision N. 07/2005, which divided the then subgroup of 'Energy and Mining' into two new ones. The motivations that led to this separation, according to the document, was the distinct nature of the issues presented in both themes. Besides, some of the most relevant documents signed in Mercosur were consequence of the SGT-9, such as those already

[201] See: http://focem.mercosur.int/es/que-es-focem/.

discussed (Decisions N. 10/1998 and Decision N.10/1999). The existence of an Ad Hoc Group on Biofuels (GAHB) was established by Decision N. 49/2007.

In this sense, energy integration issues are a major topic at the Meeting of Ministers of Mines and Energy (RMME), part of the Common Market Council (CMC), as well as of the Sub-Working Group (SGT-9)[202] and Mercosur Ad Hoc Group on Biofuels (AHBG), both subordinate to the Common Market Group (CMG). On the other hand, environmental issues are undertaken by SGT-6, which works close to a preparatory technical commission for the Meeting of the Environment Ministers (RMMA), having a more political tone.

Since 2011, SGT-6 has focused on: (i) non-tariff measures related to environmental aspects; (ii) economic competitiveness; (iii) incorporation of an environmental component to governmental sectorial policies; (iv) mechanisms to improve environmental management; (v) operationalization and streghtening of Mercosur Environmental Information System; (vi) environmental sustainability, production, substances and waste management; and (vii) keeping up-to-date with the global environmental agenda. **Figure 19** presents the evolution of SGT-6 and SGT-9 meeting frequencies, being 66 of SGT-6 (1996-2015) and only 16 of SGT-9 (2005-2011). What it is possible to perceive beforehand is that SGT-6 meetings have become even less frequent and that, regarding SGT-9 meetings, there is no public information pre-2005 and post-2011.

[202] The SGT-9 was created during the period of restructuring of the energy sectors of the different countries of the 1990s. Discussions are also being carried out within the Ad Hoc Group on Biofuels (GAHB).

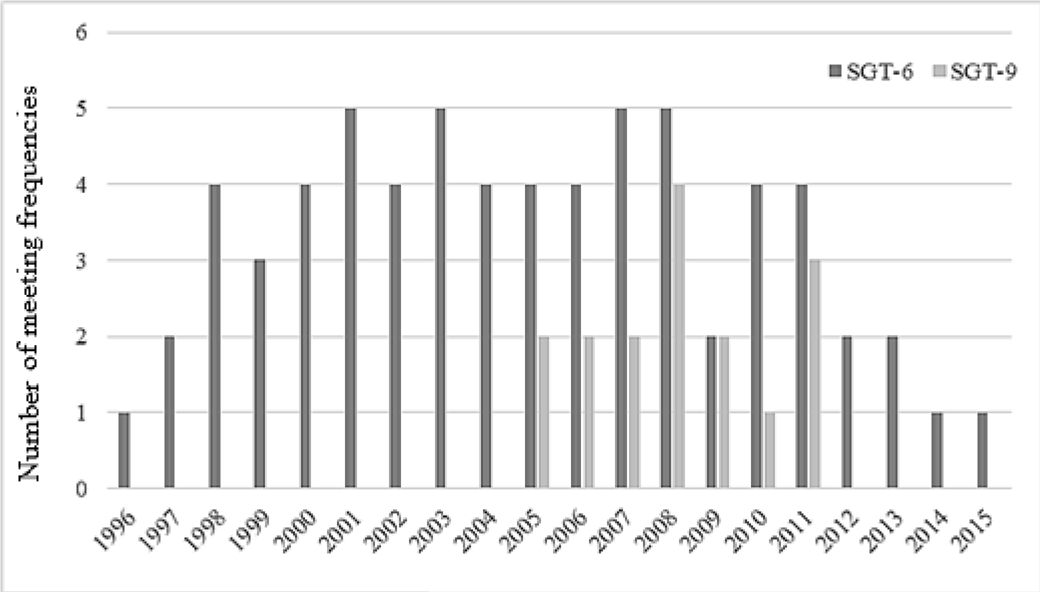

Figure 19. Evolution of SGT-6 and SGT-9 meeting frequencies (1996-2015)

Source: Own elaboration based on the website of Mercosur

Based on the meeting minutes from 2005 to 2010 and the majority referring to the years 2000 to 2005, it can be said that the vast majority of the delegated actions were fulfilled, but it should be noted that many were postponed or obtained partial compliance status (MENEGHINI and VOIGT, 2011). Internal factors, such as distinct political interests among the countries as well as the change of representatives at meetings; and external factors, such as the involvement of other players in the energy sector (private sector, other international institutions) and the complexity of the sector can be seen as influencing the results. Thus, it can be concluded that SGT-9 did not act to structure and coordinate concrete policies or projects on regional energy integration. In the analyzed period, it only worked on (i) the harmonization of energy regulation in order to facilitate exchanges; (ii) the elaboration of inventories on the electric sector; (iii) feeding databases to foster decisions in other instances; and (iv) the analysis of financial, legal and tax aspects of the sector. Although SGT-9 has daring objectives, they ended up not being reached by several reasons.

In this sense, it is perceived that the SGT-9 lost some of its relevance and ceased meeting after the creation of UNASUR Energy Council[203], the corresponding technical forum, and the negotiations of the UNASUR energy integration treaty. This is due to the nature of Latin American regional integration processes characterized by the overlap of initiatives, which often deal with the same theme.

Bringing this discussion to the present scenario, it is worth noting that the political-economic fragility of some countries increases the risk of insecurity and mistrust between countries when we talk about advancing in regional energy integration. Therefore, as highlighted in section 2.3, it is important that there is a legal-institutional framework for project and initiatives coordination and control in the energy sector. However, it was not up to member countries to prioritize energy integration within Mercosur, nor did Mercosur institutional bodies in charge of this agenda move forward. Consequently, Mercosur countries ended up choosing to open markets to free competition and to foment simple international interconnections and few binational plants as the grounds for energy strategies valid for the bloc.

Jointly, there was inability of national governments and Mercosur to advance the regional energy integration agenda. Previous sections of this chapter focused on how each of the States Parties presented physical, market and institutional asymmetries. Thus, **Table 15** and **Table 16**, respectively, sum up how the electric and hydrocarbon sectors vary in Argentina, Bolivia, Brazil, Paraguay, Uruguay and Venezuela.

[203] UNASUR will be presented and discussed in section 4.2.

Table 15. Comparative analysis of electric power industry in Mercosur countries

Country	Policy and Regulation						Segments				Studies and Planning
	Ministry	Policies and Guidelines	Regulation and Supervision	Municipal regulators	Manage wholesale electric market	Advice and monitoring [2]	Generation	Transmission	Distribution	Commercialization	
Ar	MINEM	MINEM	ENRE[1]	24	CAMMESA	CFEE	Private and state-owned companies, Yacyretá, Salto Grande	SADI	Majority private	CAMMESA	Secretariats of MINEM
Bo	ME	VMEEA	AFCSE	-	CNDC	-	COBE, ENDE	ENDE, ISA	Privados companies	-	VMATE, EBIH
Br	MME	CNPE	ANEEL	ABAR	ONS	CNPE, CMSE, CGEE, SSE/MME	Private and state-owned companies, Eletrobras, Itaipu	Eletrobras, CPST, CUST, CCT, CCI	ABRADEE, DIT, Eletrobras	CCE, ACR, ACL, CCEAR, Eletrobras	EPE, SPG-MME
Py	VMME-MOPC	ANDE	ANDE, CNEP, CONAM, SEAN	-	-	-	ANDE, Itaipu, Acaray, Yacyretá	ANDE	ANDE	-	Energy Resources Department
Uy	MIEM	DNE-MIEM	URSEA	-	ADME	DNE-MIEM	UTE, private companies	UTE	UTE	UTE, private companies	DNE-MIEM
Ve	MPPEE	The National Development Plan	MPPEE	-	-	Corpoelec	Corpoelec	Corpoelec	Corpoelec	Corpoelec	MPPEE

Source: Own elaboration; [1] = but the electrical regulation is provincial (there are 24 regulators); [2] = national and municipal governments.

Table 16. Comparative analysis of O&G industry in Mercosur countries

Country	Ministry	Policies and Guidelines	Regulation and Supervision	Exploration and Production	Refining and Transportation	Comercialization
Ar	MINEM	MINEM	ENARGAS (gas), MINEM (oil)	YPF and private companies (Petrobras Argentina, Pan American Energy Sucursal Argentina, LLC, Total Austral)	MINEM and private comapnies	MINEM
Bo	MH	-	ANH	Petrobras Bolivia, YPFB, YPFB Andina S.A., YPFB Chaco S.A., YPFB Petroandina S.A.	Petrobras Bolivia, YPFB Refinación S.A., YPFB Transporte S.A., YPBF Transierra S.A., YPFB Logistica S.A.	YPBF Aviación, Flamagas S.A
Br	MME	Presidency of the Republic, National Congress, CNPE, MME	ANP, environmental inspection agencies, RFB	Petrobras, IOCs, independent actors, supply industry to the oil sector, companies of the O&G	Petrobras and private companies	Traders, Petrobras, PPSA
Py	VMME-MOPC, MIC	VMME-MOPC, MIC	VMME-MOPC, MIC	Petropar and private companies	Petropar	Petrobras, ESSO, COPETROL, Barcos y Rodado, PUMA, GAS CORONA, HIPASA, SUGAS, Lima Gas, Gas del Este, Yacyretá, Acaray Gas, COPESA, Petrogas, Norte Gas
Uy	MIEM	DNE	URSEA	ANCAP in association with international private companies (Total, BP, BG, TULLOW Oil, Petrel-Schuepbach, YPF)	Petrobras Uruguay (GN distribution), in association with ANCAP	ANCAP DUCSA
Ve	MPetroMin	The National Development Plan	MPetroMin (oil), ENAGAS (gas)	PDVSA or other concession holders (gas), PDVSA (oil)	PDVSA	PDVSA

Source: Own elaboration.

Identifying the asymmetries that exist between the Mercosur countries, which imply different energy policies, is fundamental to understand 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 issue, particularly when it comes to developing countries.

Thus, although there are advances in institutional and legal matters within Mercosur concerning regional energy integration, it can be seen that in practice little progress has been made. More recently, it can be argued that the ongoing attempts to revive Mercosur are concentrated in the commercial sphere, in view of efforts to negotiate a trade agremeent with the European Union (EU). Regarding the energy policies of the Mercosur countries, they do not follow a pattern, each country being responsible for defining its agendas without a common regional plan. However, the recent Mercosur Social Summit in Brazil can be seen as a positive example in this field, where dynamism is still to be found. Thus, in the area of infrastructure, which requires medium/long-term planning and investment, it will be necessary to wait for a more adequate political and (macro)economic scenario.

4.2 IIRSA-UNASUR

As already discussed, Latin America is characterized by an overlap of regional integration processes, which often deal with similar issues. In terms of energy, this occurs between Mercosur, the Initiative for Regional Infrastructure Integration South America (IIRSA), the Union of South American Nations (UNASUR), Regional Energy Integration Commission (CIER)[204] and the Latin American Energy Organization (OLADE).

The CIER was founded in 1964, during the first Regional Congress of Electrical Integration (Montevideo, Uruguay). It is defined as a non-governmental organization that

[204] CIER is composed of different national support committees. In the case of Brazil, the committee in charge is the Brazilian Committee of CIER (BRACIER), created in 1966. BRACIER is a non-profit, nongovernmental entity that currently comprises 41 companies/entities in the Brazilian electricity sector, including the Electrical Energy Research Center (CEPEL), Eletrobras and the National System Operator (ONS).

gathers 198 companies and organizations of the electricity sector in the ten South American countries. True to its primary purpose, it promotes and leads the integration of electricity sectors as one of the means to boost regional development and prosperity[205]. The Latin American Energy Organization (OLADE) was created in the context of the international energy crisis of 1973, it is made of 16 member countries of Latin America and the Caribbean. It is represented in each country by the coordinators in the ministries or energetic entities.

Both CIER and OLADE are responsible for the systematization and elaboration of energy data and reports for LAC countries. However, they do not constitute regional integration initiatives, although they do contribute to this in some way. In this sense, even if they touch on energy infrastructure in some way, the focus of this section will be on the Initiative for Regional Infrastructure Integration South America (IIRSA)[206], because it is the broadest one in the subcontinent, and consequently UNASUR. The initiative includes coordination mechanisms among governments, multilateral financial institutions and the private sector, and aims to coordinate investment plans and programs, as well as to prioritize Integration and Development Hubs (EID).

The IIRSA was created during the First Meeting of South American Presidents (Brasília, Brazil) in 2000, and the twelve countries of South America (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Guyana, Paraguay, Peru, Suriname, Uruguay and Venezuela) take part of it. It has three main areas of activity, that is, energy, transport and communications. Among the guiding principles of IIRSA, we can highlight: (i) open regionalism: in line with the Economic Commission for Latin America and the Caribbean (ECLAC) concept of guaranteeing liberalization policies in relation to third parties, while favoring the accession of new members to the agreements; (ii) Integration and Development Hubs (EIDs); (iii) economic, social, environmental and political-institutional sustainability; (iv) increase in the production value added; (v) information

[205] It is worth noting that in the new strategic framework of the CIER, approved in the Central Committee of Lima (April 2015), the following new concepts are defined. It defends that in 2020 CIER will be a global reference organization recognized for its contribution to the integration and development of the Latin American energy sector. The mission seeks to promote the integration of the regional energy sector with emphasis on the interconnection of systems, the integration of markets, mutual cooperation between its members, knowledge management and the promotion of sustainable businesses (CIER, 2016b).

[206] IIRSA represents a multinational, multisectoral and multidisciplinary initiative that includes coordination mechanisms between governments, multilateral financial institutions and the private sector (BIATO, 2016). It is financed by Brazilian Development Bank (BNDES), Inter-American Development Bank (IDB), Andean Development Corporation (CAF), and Financial Fund for the Development of the Plata Basin (FONPLATA).

technology; (vi) normative convergence; and (vii) public-private coordination. By the way, there is a strong relationship between these principles and the main criticisms of IIRSA itself.

It is worth highlighting the relevance of the Sectoral Integration Processes (PSIs), which aim to identify regulatory and institutional obstacles that prevent the development of basic infrastructure in the region and propose actions to overcome them. Typically, these PSIs seek to harmonize regulatory frameworks. Through the analysis of **Table 18**, we will see the nonexistent weight of the projects associated specifically with harmonization of regulatory frameworks within the IIRSA-COSIPLAN project portfolio 2016.

Since 2011, IIRSA was incorporated into the South American Council of Infrastructure and Planning (COSIPLAN), which is a forum for political and strategic discussion through consultation, evaluation, cooperation, planning and coordination of efforts and articulation of programs and projects in order to foster regional infrastructure integration among UNASUR[207] member countries. In the same year, IIRSA creates two instruments to guide its work for the next ten years: (i) the Strategic Action Plan 2012-2022 (PAE); and (ii) the Integration Priority Project Agenda (APIs).

In turn, UNASUR was created on May 23 2008, when the Constitutive Treaty of the Union of South American Nations was approved[208], in which Quito (Ecuador) was the permanent city designated to General Secretariat and Cochabamba (Bolivia) was the permanent city designated to the Parliament. However, it is important to stress that UNASUR is the result of a series of discussions and meetings.

In 2004, at the Meeting of Presidents of South America, held in Cuzco (Peru), the South American Community of Nations (CSN)[209] was created. The CSN was born to integrate regional processes developed by Mercosur and the Andean Community (to avoid the aforementioned reproduction of overlaps in regional initiatives). In 2005, in Brasília (Brazil), and 2006, in Cochabamba (Bolivia), the heads of state of member countries established a strategic plan to consolidate a common agenda in the region. However, it is only in 2007, during the South American Energy Summit, on Isla Margarita (Venezuela),

[207] One of the reasons why it will be necessary to evaluate UNASUR in this section.
[208] See: https://www.unasursg.org/images/descargas/DOCUMENTOS%20CONSTITUTIVOS%20DE%20UNASUR/Tratado-UNASUR-solo.pdf.
[209] The role of regional energy integration is already highlighted in this Meeting.

that the heads of states changed the name of the South American Community of Nations (CSN) to the Union of South American Nations (UNASUR).

It is noteworthy that from the very beginning energy was a priority in the UNASUR agenda. Among the general documents, declarations, agreements, communiqués and protocols, UNASUR signed 46 documents related to energy. The following important energy integration frameworks will be analyzed: (i) Declaration of Caracas (2005); (ii) Declaration of Cochabamba (2006); (iii) Declaration of Margarita (2007); (iv) Alignments of the South American Energy Strategy (2008); and (v) structure of the South American Energy Treaty (approved in 2010).

The **Declaration of Caracas** (2005), signed in Venezuela, is the first meeting of energy ministers of the South American Community of Nations (CASA). The priority of energy integration was defended, referring to the Consensus of Guayaquil[210] (2002), in Ecuador, when integration in the energy sector was considered essencial to success of regional integration as a whole. Therefore, the importance of regional infrastructure for energy transport is emphasized, as is the strategic role that energy has in the economic and social development of South America.

The **Declaration of Cochabamba**[211] (2006), signed in Bolivia, is often remembered as the 'cornerstone of the South American integration process'. The main objective was to stimulate energy integration in order to reduce the region's socio-economic asymmetries. Since then, there has been concern about sustainable development. The 'Presidential Declaration on South American Energy Integration' is accomplished, which is the first of its kind, at the South American level, within the framework of developing the institutionalization of this sector. It also represents a more far-reaching view, identifying the principles that will guide the process of political and normative convergence in terms of regional energy integration, as well as the dimensions that it should take into account (CAF, 2013e).

The eight principles are the following: (i) cooperation and complementation; (ii) sovereign right to the use of natural resources and to manage exploitation rates; (iii) respect for the regulation of each country and the modes of ownership used by each State for the development of its energy resources; (iv) solidarity and reciprocity; (v) purpose of

[210] See: http://www20.iadb.org/intal/catalogo/PE/2010/05282.pdf.
[211] See: http://www.isags-unasur.org/uploads/biblioteca/1/bb[611]ling[1]anx[1825].pdf.

eliminating the asymmetries between the States; (vi) respect for the sovereignty and self-determination of peoples; (vii) territorial integrity; and (viii) common legal framework for energy integration.

The **Declaration of Margarita**[212] (2007) was signed at the II Meeting of Energy Ministers of the South American Community of Nations (CSN), in Isla Margarita, and it created UNASUR, as well as the South American Energy Council (CES)[213]. In addition, based on the principles outlined in this declaration, it is suggested to prepare a proposal for alignments of the South American Energy Strategy, the Action Plan and the Energy Treaty of South America, documents that originally should have been discussed during the course of the III South American Summit of Nations. As mentioned, the relationship between UNASUR and energy is very close, even because the organization was born during the First South American Energy Summit.

The **Alignments of the South American Energy Strategy**[214] (2008) focus on the five South American energy integration advices (i) emphasizing the need to increase national and regional coordination; (ii) to extend and deepen the processes of sector integration; (iii) to boost the search for new energy sources; (iv) to establish regional mechanisms that help countries of the region in crisis; and (v) to establish legal and technical frameworks to support such exchanges.

These meetings resulted in the creation of twelve guiding principles of the energy integration strategy of UNASUR, which model the activities of the Energy Council, namely: (i) cooperation and complementation; (ii) solidarity among peoples; (iii) respect for the sovereignty and self-determination of peoples; (iv) sovereign right to establish criteria for sustainable development and the use of renewable and non-renewable natural resources, as well as to manage the rate of exploitation of these resources; (v) regional integration in search of the complementarity of countries in the balanced use of resources for the development of their peoples; (vi) respect for the modes of ownership that each State uses for the development of its energy resources; (vii) energy integration as an

[212] See: http://www.isags-unasur.org/uploads/biblioteca/1/bb[613]ling[2]anx[1830].pdf.
[213] CES is born and it creates guidelines for the energy integration of the region. It is also worth noting that CES is one of the oldest and most active councils of UNASUR, demonstrating again that energy integration has been central to the project developed by the organization since verey the creation of UNASUR.
[214] See: https://www.unasursg.org/images/descargas/ESTATUTOS%20CONSEJOS%20MINISTERIALES%20SECTORIALES/LINEAMIENTOS%20DE%20ESTRATEGIA%20ENERGETICA%20SURAMERICANA.pdf.

important tool to promote social, economic and poverty eradication; (viii) universal access to energy as a citizen's right (as stressed in subsection 2.1.1); (ix) sustainable and efficient use of the region's resources and energy potential; (x) articulation of energy complementarities to reduce existing asymmetries in the region; and (xii) recognition of States, society and industry as key players in the integration process. It is then clear that some of them are based on the eight principles of 'Presidential Declaration on South American Energy Integration', created by the Declaration of Cochabamba (2006).

Based on these principles, during the same meeting that created the alignments of UNASUR's energy strategy, an **Action Plan** based on fifteen strategic action points were proposed to be developed with the goal of expanding integration: (i) to promote security in the energy supply of the region; (ii) to promote regional energy exchange; (iii) to strengthen regional energy infrastructure; (iv) to implement complementation mechanisms between national state hydrocarbon companies and other types of energy; (v) to provide the exchange and transfer of technology, as well as the training of human resources; (vi) to encourage regional energy development in order to provide a rational consumption model capable of preserving the environment; (vii) to promote industrialization and energy development and its regional complementation; (viii) to promote harmonization of regulatory and trade processes associated with energy integration; (ix) to incorporate the regional energy integration component into national energy planning; (x) to promote the efficient use of energy and the exchange of experience in this field; (xi) to boost the development of renewable and alternative energies, such as biofuels, wind, solar, nuclear, tidal, geothermal, hydro, hydrogen, among others; (xii) to stimulate the association between the public and private sectors; (xiii) to support the maintenance of existing bilateral, regional and subregional agreements, as well as to facilitate the negotiation of future agreements; (xiv) to promote a balanced relationship between producing and consuming countries; and (xv) to advance proposals for the convergence of national energy policies considering the legal framework in force in each country. Noteworthy is the amount of action verbs in the Action Plan.

Finally, the approval of the structure of the **South American Energy Treaty** (2010), signed at the Declaration of Los Cardales (Argentina), should be mentioned. In fact, there is an outline, not a full text on the Treaty. However, it is believed that it could represent a milestone in South American energy integration.[215] **See Appendix F**.

Recently, at the IV Meeting of the South American Energy Council of UNASUR (2015) a 2015-2016 working plan was established, whose focus is to promote regional energy and gas interconnection networks and reach regional agreements that benefit the region in terms of energy.[216] The V Meeting of the South America Energy Council of UNASUR[217] was held in (Quito) Ecuador, July 2016. In 2017, there was no CES meeting.

Although the UNASUR Energy Council is responsible for formulating general policies that should lead to energy integration of South America, the South American Council of Infrastructure and Planning (COSIPLAN) has been directly playing a crutial role. As already presented, COSIPLAN belonged to the South American Regional Infrastructure Integration Initiative (IIRSA), and it is currently part of UNASUR. It is important to mention that the COSIPLAN Project Portfolio is a set of works with a strong impact for regional integration and socio-economic development.

Based on official data from UNASUR-COSIPLAN (2016), the investment portfolio estimated in 2016 is of US$ 191,420.10 million and has 581 projects. Considering this amount, 5 (0.9%) are multinational, 94 (16.1%) are binational and 482 (83%) are nationals. Analyzing the projects by type of financing, we note that 475 (US$ 117,691 million) are financed with pure public funding, 71 (US$ 35,926 million) with pure private funding and 35 (US$ 37,803.1 million) with public-private or shared funding. **Table 17** presents the asymmetry that exists in terms of project numbers and estimated investment value (US$ million) in the different EIDs.

[215] The only similar experience in the world is the Energy Charter of the European Union, whose elaboration took more than ten years (SIMÕES, 2011).
[216] See: http://www.iri.edu.ar/wp-content/uploads/2016/10/bo-alatina57-unasur-consejoenergetico.pdf.
[217] See: http://www.iri.edu.ar/wp-content/uploads/2016/10/bo-alatina57-unasur-consejoenergetico.pdf.

Table 17. UNASUR-COSIPLAN 2016 Project Portfolio, by EID

EID		Number of projects		Estimated investment (US$ million)	
		Amount	**%**	**Amount**	**%**
AMA	Amazonia	72	12.4	27,022.80	14.1
AND	The Andes	66	11.3	27,995.30	14.6
CAP	Capricorn	81	13.9	16,691.20	8.7
GUY	Guyana Shied	20	3.4	4,581.30	2.4
HPP	Paraguay-Parana Waterway	89	15.3	6,325.10	3.3
IOC	Central Interoceanic	63	10.8	11,498.50	6.0
MCC	Mercosur-Chile	120	20.6	60,971.20	31.8
PBB	Peru-Brazil-Bolivia	24	4.1	32,008.40	16.7
DES	South	47	8.1	4,506.70	2.4
Total		**582**	**100.0**	**191,600.50**	**100.0**

Source: Own elaboration based on UNASUR-COSIPLAN (2016).

Table 18 analyzes the number of projects by country. There is a huge asymmetry. Argentina is the country with the most projects (178 projects, US$ 48,565.9 million), followed by Brazil (94, US$ 82,413.8 million), Chile (73, US$ 16,105 million) and Peru (73, US$ 11,801.7 million). On the other hand, the countries with the fewest projects in terms of quantity and financial volume are Guyana (8, US$ 911.9 million) and Suriname (7, US$ 3,831.9 million).

Table 18. UNASUR-COSIPLAN 2016 Project Portfolio, by country and type of project

Country	Number of projects			Estimated investment (US$ million)
	National	**Binational**	**Multinational**	
Ar	144	34	-	48,565.9
Bo	32	19	1	10,578.7
Br	67	24	3	82,413.8
Cl	57	17	-	16,105.0
Co	19	13	1	4,743.6
Ec	20	19	1	19,609.1
Gu	3	2	3	911.9
Py	43	22	1	18,002.6
Pe	50	21	1	11,801.7
Su	3	1	3	3,831.9
Uy	33	9	-	5,445.2
Ve	11	7	2	2,109.5

Source: Own elaboration based on UNASUR-COSIPLAN (2016).

Table 19 shows that 518 projects (89.2%) come from the transport sector (US$ 133,958.90 billion), 56 projects (9.6%) energy sector (US$ 57,419.70 billion), and 7 projects (1.2%) communication sector (US$ 41.50 million). Howsoever, it is worth mentioning that the total amount of projects in the portfolio has evolved considerably over time. In 2003-04, for example, they were 335 projects (US$ 37,425.0 million), while in 2010 there were 524 (US$ 96,119.2 million). As already presented, in 2016 they were 581 projects (US$ 191,420.1 million). During the whole period, projects totaled up US$ 1,255.41 billion.

Table 19. UNASUR-COSIPLAN 2016 Project Portfolio, by sector and type of project

Sector and Subsector	Transport				Energy				Communications			
	Number of projects	Investment			Number of projects	Investment			Number of projects	Investment		
		Amount (US$ million)	% sector	% total		Amount (US$ million)	% sector	% total		Amount (US$ million)	% sector	% total
Air	24	7,530.40	5.6	3.9								
Road	258	63,476.50	47.4	33.2								
Railway	61	47,921.40	35.8	25.0								
River	76	2,892.90	2.2	1.5								
Maritime	38	10,493.70	7.8	5.5								
Multimodal	14	679.30	0.5	0.4								
Border crossings	47	964.70	0.7	0.5								
Energy generation					25	46,859.50	81.6	24.5				
Interconnection of energy					31	10,560.20	18.4	5.5				
Interconnection of communications									7	41.5	100.0	0.02
Total	**518**	**133,958.9**	**100.0**		**56**	**57,419.7**	**100.0**		**7**	**41.5**	**100.0**	

Source: Own elaboration based on UNASUR-COSIPLAN (2016).

In terms of funding sources, there are pure public, pure private and public/private investment. For the transportation sector, 65% of the investments are public, 26% are private and 9% are public/private. In the energy sector, 53% of investments are public, 3% are private and 44% are public/private, while in the transportation sector, 100% of investments are public (UNASUR-COSIPLAN, 2016). We noticed again that in terms of investments the profile changes a lot for each sector, highlighting the share of public investments in the guarantee of investments in physical infrastructure in South America.

If we specifically analyze the API 2016 agenda, 89.2% of the individual API projects correspond to the transport sector and represent 70% of the total estimated investment. The remaining 9.6% belongs to the energy sector, with an estimated investment of 30%. Regarding the sub-sectoral composition of the individual projects, it is observed that road projects account for 44.4% of the API and demand about 33.2% of the total investment (UNASUR-COSIPLAN, 2016).

Table 20 and **Figure 20** show the evolution of the UNASUR-COSIPLAN total and energy projects, in number, in value (millions US$) and share (%) during 2003-2017. Although the total investment increased 71.3% in the period 2011 to 2017, the share of energy projects fell 37.0% in the same period (16.2 percentage points drop).

Table 20. Evolution of the UNASUR-COSIPLAN total and energy projects (2003-2017)

Projects and Investment	2003-04	2005-06	2007	2008-09	2010	2011	2012	2013	2014	2015	2016	2017
Number of projects	335	349	504	510	524	531	544	583	579	593	581	562
Energy projects						61	60	59	54	56	56	54
% energy projects						11.5	11.0	10.1	9.3	9.4	9.6	9.6
Investment (Millions US$)	37,425.0	37,880.0	68,271.4	74,542.0	96,119.2	116,120.6	130,139.1	157,730.5	163,324.5	182,435.7	191,420.1	198,901.4
Energy investments						50,931.3	49,482.2	50,830.2	54,670.1	52,715.7	57,419.7	54,926.7
% energy investments						43.9	38.0	32.2	33.5	28.9	30.0	27.6

Source: Own elaboration based on UNASUR-COSIPLAN (2011, 2012, 2013, 2014, 2015, 2016, 2017).

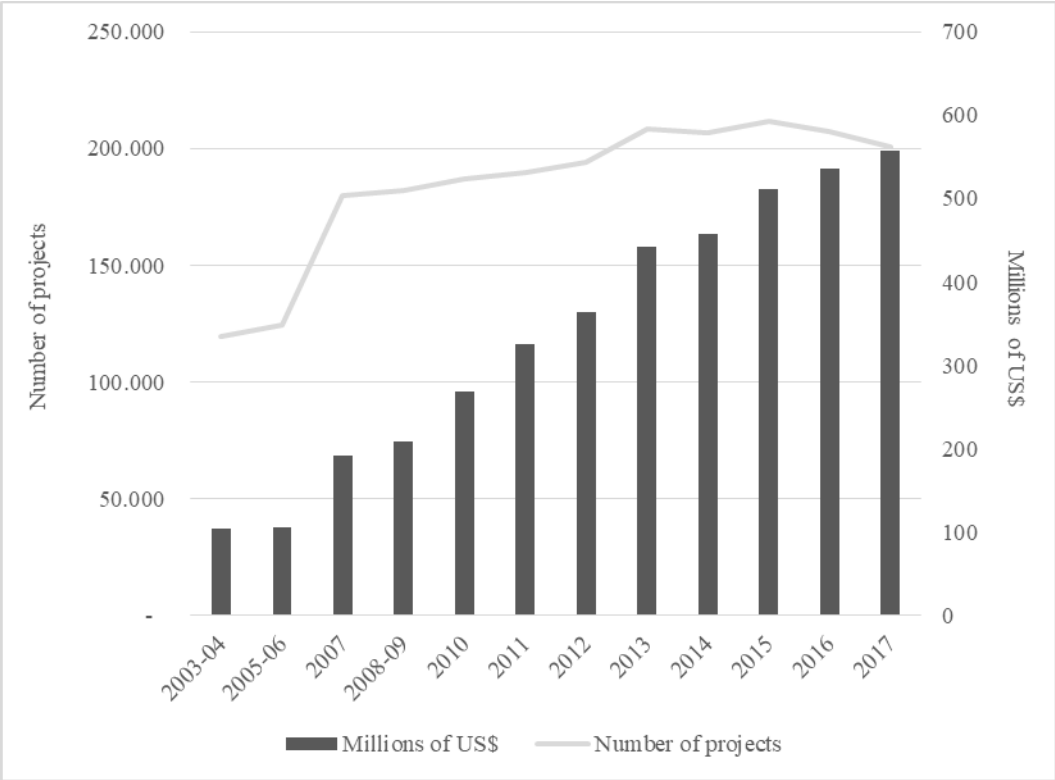

Figure 20. Evolution of the UNASUR-COSIPLAN total projects (2003-2017)

Source: Own elaboration based on UNASUR-COSIPLAN (2011, 2012, 2013, 2014, 2015, 2016, 2017).

Due to the intergovernmental nature of both Mercosur and UNASUR[218], both institutions, although dealing with energy issues in the regional level, end up presenting limitations to their performance. Consequently, the main institutions that should promote regional energy integration actually play a secondary role in proposing regional policies without any binding enforcement mechanisms. Mercosur, through FOCEM, and UNASUR, through UNASUR-COSIPLAN projects, provide funds for projects in infrastructure to promote the structural convergence of the countries of the region, reducing the asymmetry between them. Nevertheless, in spite of the number of regulations, plans, principles and strategic alignments, the data presented in sections 3.7 and 3.8 show that energy projects carried out by both institutions (i) are spatially concentrated in certain regions; (ii) are few (if compared to the total available value); and (iii) have been falling over time.

[218] In the intergovernmental model of Mercosur and UNASUR, National States through their respective Ministers of Energy have been the protagonists.

Moreover, there are recent challenges for UNASUR. The first one is that some countries in South America, such as Peru, Mexico and Colombia, are focused on the Pacific Alliance. Another challenge arises from the political-economic conjuncture of certain countries of the region, with particular emphasis on Brazil and especially on Venezuela. Both countries play a key role in regional energy supply and demand, the first in terms of regional imports of electricity and natural gas (from South America), and the second as an exporter of oil and gas (for Latin America and Caribbean).

Concerning the South American Energy Treaty, it seems very ambitious and therefore hard to move forward. So far, there is only the index. Albeit being an intergovernmental institution, decisions in UNASUR have to be by consensus, which makes the approval of new agendas and projects still more difficult.

Regionally, one cannot ignore the region of the Andes Mountains Range[219], the Amazon Forest, the Atacama Desert and Patagonia Glaciers since all of them represent geographical barriers to the effective regional energy integration. Indeed, they impose technical difficulties incurring higher costs. In addition, overlapping regional integration initiatives make the energy integration process even more difficult, since there is no alignment between the different institutions. These institutions sometimes have different positions on the same issue, as occurred with regard to the existence or not of coup d'état in Brazil between Mercosur and UNASUR.

[219] Colombia seems to be the case where the Andes Mountains was overcome by interconnected electrical systems. Albeit in a national context (rather than regional one), this experience may serve as an example for future integration projects in Andean regions.

5. Energy index and modeling

This chapter, as well as the previous two, is also divided into two main sections: SEES index (section 5.1) and OSeMOSYS-SAMBA modeling (section 5.2). In the first section, a new hybrid index called socio-environmental-energy security (SEES) is created, whose main objective is to analyze the evolution of the energy policies of Mercosur (countries) in the past (1990-2010). Then, the second section proposes energy scenarios using the Open Source Energy Modelling System - South America Model Base (OSeMOSYS SAMBA), a model for planning for the expansion of long-term energy systems, whose objective is to analyze present and possible integration scenarios in the future (2013-2050). Four scenarios are modeled: reference integration scenario (RIS), weak integration scenario (WIS), moderate integration scenario (MIS) and otimistic integration scenario (OIS), considering expansion and new international interconnection lines, new binational hydroelectric plants as well as new contractual arrangements (swaps).

Undoubtedly, we consider here the possible (inherent) limitations of quantitative analytical tools. Because they assume a diversity of parameters, axioms and assumptions, they aim to simulate and predict future scenarios and possibilities that, once the inputs of the model are true or reasonable, are particularly useful in developing policies and strategies that contribute to the anticipation and planning of decision makers, whether public or private.

Scenarios methodology (i) can expand the way reseachers and policy-marks think, once it provides a range of possible outcomes; (ii) uncover inevitable or near-inevitable futures, considering social, political and economic trends, as well as scheduled events; and (iii) allow people to challenge conventional wisdom thinking outside the box, mainly because sometimes there is a very strong status quo bias (ROXBURGH, 2009). When it comes specifically to energy scenarios, it is necessary to consider some recent challenges that need to be added to the analysis, incorporating for example new low-carbon goals (in line with section 2.1.2 and SEES index). This relatively new dimension of the scenarios means that in addition to the traditional factors like technology development, demographic, economic, political and institutional considerations, there is another aspect of the modern energy projections related to the coverage, timing, and stringency of policies to mitigate greenhouse gas emissions and air pollutants (PALTSEV, 2016).

In order to avoid incurring these potential errors and traps inherent to this methodology, the two sections are based on a large literature review. The first one deals with existing and published data, so its risk is reduced. The second section, in addition to literature data, incorporates information from the expansion plans of the countries considered.

5.1 SEES Index[220]

As shown in section 2.1, the concept of energy security has raised controversies over its definition, scope and approaches for decades. Studies on energy security have been criticized for a number of reasons, including that they employ a narrow interpretation of this 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, like in KANCHANA and UNESAKI (2014), IEA (2013), MARTCHAMADOL and KUMAR (2013), SOVACOOL *et al*. (2011), LÖSCHEL *et al*. (2010), KEMMLER *et al*. (2009), VERA and LANGLOIS (2007), Department of Energy and Climate Change (2006) and IAEA (2005). Indicators may facilitate orientation in a complex world, condensing large amounts of information into a recognizable pattern.

As ANG *et al*. (2015) highlight, the weight 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. They evaluate that in recent studies the environmental dimension occupies the second area most addressed, only behind the economic one; in turn, the social aspects occupy only the fifth position, behind 4As and energy supply.

Moreover, the authors perceive that the weight of both themes varies greatly between official reports, journals and other publications; the environmental theme is cited in about 40% of journals and only about 15% of official reports; in turn, the percentage of social agenda is 30% and 40%, respectively. Ergo, it is noteworthy to reinforce how the different sources attribute different weights to the same variables, which once again ratifies the lack of consensus on the concept of energy security.

[220] *Energies* published the index in December 2017. See: SANTOS *et al*. (2017b).

Subsection 2.1.1 and subsection 2.1.2 showed the relevance to take into account social and environmental dimensions when it comes to energy security, particularly when analyzing developing countries. DEVINE-WRIGHT *et al*. (2017), SILVAST (2017) and BATEL *et al*. (2013**)** reinforce the need to consider social variables and social studies in the understanding of energy markets. KISSEL *et al*. (2009**)** highlight the relevance of the environmental variable, analyzing renewable energy law for emerging markets in South America.

Therefore, after (i) evaluating the concept of energy security (**Chapter 2**); (ii) analyzing national energy markets structures (**Chapter 3**); and (iii) knowing regional mechanisms of Mercosur and UNASUR related to the energy issue as well as perceiving their differences (**Chapter 4**), it is important to evaluate how they are translated into 'energy security'. To this end, this section proposes to create a hybrid approach called socio-environmental-energy security (SEES) index in order to assess the evolution of energy policies results in the 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 (ANG *et al*., 2015), 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).

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 (in a regional dimension)[221].

To guarantee sustainability, we must provide equal weight to economic, social, and environmental aspects (KISEL *et al*., 2016). 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 (due to increasing demand,

[221] Note that SEES index is 100% in line with discussions carried out **Chapter 2**, subsection 2.1.1, subsection 2.1.2 and subsection 2.1.3.

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 (ANG, CHOONG and NG, 2015). These indicators, as anticipated, were divided into three dimensions[222]: 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 SEES 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 21**, the energy dimension incorporates indicators relating to (geo)political (E1 and E2) and technological (E4) matters. It is completely in line with regional integration needs, once must take into account technical, regulatory and commercial issues, without ignoring the relevance of the political factors that guide these processes.

[222] SEES index is related to the famous pillars of sustainability (social, economic, and environmental), as well as energy trilemma (energy equity, energy security, and environmental sustainability).

Table 21. Socio-environmental-energy security (SEES) index.

Dimension	Code	Indicator	Unit
Social (S)	S1	Access to electricity, rural	% of rural population
	S2	Access to electricity, urban	% of urban population
	S3	Electricity consumption per capita	kWh per capita
	S4	Total final consumption (TFC) per capita	toe per capita
	S5	Total primary energy supply intensity	toe per thousand 2005 US$
Energy (E)	E1	Fuel exports	% of merchandise exports
	E2	Net oil imports/GDP	toe per thousand 2005 US$
	E3	Total natural resources rents	% of GDP
	E4	Electric power transmission and distribution losses	% of output
	E5	Investment in energy with private participation	current US$
Environmental (A)	A1	CO_2 emission per capita	tCO_2/capita
	A2	CO_2 intensity	$kgCO_2$/2005 US$
	A3	Energy related methane emissions	% of total
	A4	Nitrous oxide emissions in energy sector	thousand metric tons of CO_2 equivalent
	A5	Renewable energy consumption	% of total final energy consumption

Source: SANTOS *et al.* (2017a, 2017b) 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 (ANG *et al.*, 2015). The min-max normalization, the most popular method used in different relevant and famous studies (TONGSOPIT *et al.*, 2016, KHATIB, 2016, KAMSAMRONG and SORAPIPATANA, 2014, ZHANG *et al.*, 2013, ANGELIS-DIMAKIS *et al.*, 2012, EDIGER and BERK, 2011, SOVACOOL *et al.*, 2011, CABALU, 2010, LEFÈVRE, 2010, GNANSOUNOU, 2008, GUPTA, 2008), 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:

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

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 (it is the case of 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.

From now on, we will briefly analyze and discuss 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. Ergo, to avoid analytical bias after standardization, we present a graphical analysis only for the period from 1990 to 2010, at five-year intervals.

Figure 21 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[223].

[223] Indeed, the lack of data influences the results, affecting the graphical analysis of the SEES index. However, the graphical presentation is maintained every five years, since the same pattern will occur in section 5.2.

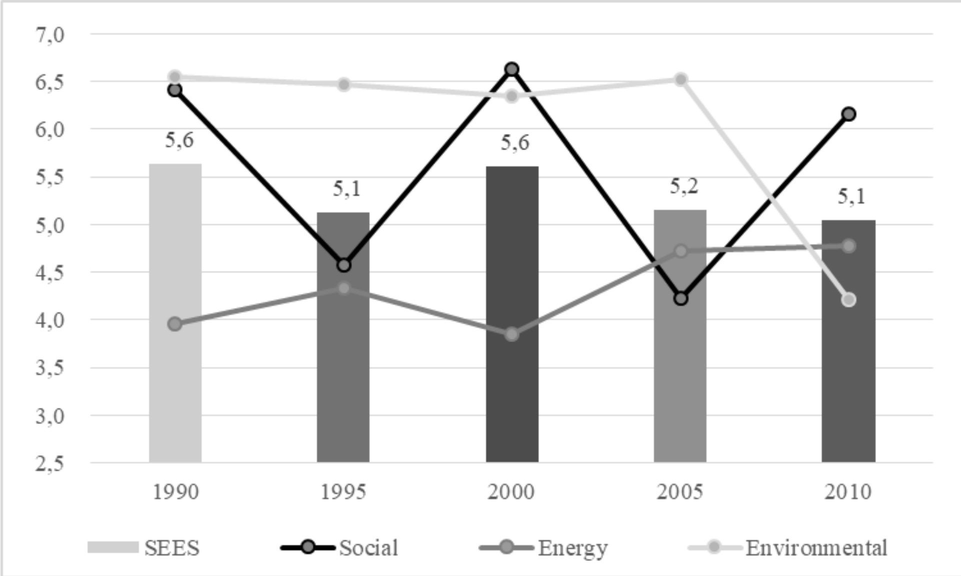

Figure 21. Evolution of SEES in Mercosur (1990–2010)

Source: SANTOS *et al*. (2017b).

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 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 for 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).

Considering the SEES index for the period from 1990 to 2010, it is perceived that it falls 0.5pp or 8.9%. This suggests that the absence of joint planning and policies among Mercosur countries in the period under analysis did not contribute to the improvement of the index, given the selected indicators.

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. Fourth, it should be noted that considering private participation in investment (current dollars) may not adequately reproduce the amount invested in the sector, especially in countries where public participation is considerable. Fifth, the environmental dimension heavily focuses on indicators that measures the impacts on climate change. 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. Besides, the choice of selected indicators affects the results.

Taking into account the social, environmental and regional dimensions in the formulation of policies (link between subsection 2.1.1, subsection 2.1.2 and subsection 2.1.3 with section 5.1), it is fundamental to evaluate the analytical trade-offs between these areas.

Regarding the social dimension, it is important to consider the trade-off between access/use of energy and development of countries. At the same time that developing countries still have regions without access to energy resources, as they develop tend to mimic the patterns of production and consumption in developed countries (FURTADO, 1974), what greatly increases per capita energy consumption. According to IRENA (2017b), a deep transformation of the way we produce and use energy is needed to achieve alternative scenarios of low-carbon emissions.

Thus, it is necessary to promote a significant change in the development path of these countries so that it becomes sustainable and responsible (ROMÁN *et al*., 2012). However, it is known that many developing countries often resort to the 'late development' argument, giving developed countries the largest share of efforts to meet the challenges they face – principle of common but differentiated responsibilities (CBDR).

It is worth mentioning that eradicating poverty has been a central agenda for the UN since the Universal Declaration of Human Rights (1948). Access to energy is already assumed as a basic right (UN, 2012, UEC, 2014) and a public good (KARLSSON-VINKHUYEN *et al*., 2012) for many. In this context, and in referring specifically to the Millennium Development Goals (MDGs), SANWAL (2014: 94) makes a critical analysis that 'the MDGs stressed meeting basic human needs, and ignored other preconditions for raising living standards, for example, energy as a basic human need'. In addition, he argues that the definition of development cooperation was narrowly defined as an aid-driven relationship, disregarding other policies (trade, investment and technology transfer).

When updating the discussion of the MDGs for the Sustainable Development Goals (SDGs) debate, it is known that energy gained relevance in the 2030 Agenda, corresponding to SDG 7. Its goals include: (i) ensure universal access to affordable, reliable and modern energy services; (ii) increase substantially the share of renewable energy in the global energy mix; (iii) double the global rate of improvement in energy efficiency; (iv) enhance international cooperation to facilitate access to clean energy research and technology; and (v) expand infrastructure and upgrade technology for supplying modern and sustainable energy services for all in developing countries.

As is clear from the SDG 7 targets, there is a central concern about universal access to modern energy services, the promotion of renewable energies and energy efficiency, as well as increased international cooperation and infrastructure. Therefore, limiting the global mean temperature rise to below 2°C would require an energy transition of exceptional scope, depth and speed (IRENA, 2017b).

With regard to the environmental dimension, it is necessary to consider the trade-off between developing countries' economic growth and greenhouse gas (GHG) emissions. ANG *et al*. (2015) argue that such a relationship will have distinct effects in the short-term and in the long-term, so it is fundamental to take into account its irregular movement. At times it is contrary to the trend of indicators such as energy intensity and total emissions. Good proxies to evaluate this trend are efficiency and productivity in the production of energy.

However, when considering environmental variables, it is necessary to take into account another potential trade-off. By promoting the substitution of renewable alternatives to conventional energy, it is possible to add risks and threats to the system, such as intermittency and high operating costs. According to IRENA (2017a), amid this accelerating transition, the variability of solar and wind energy – two key sources for renewable power generation – presents new challenges.

When considering that these alternative energies still do not scale in certain markets, in fact, costs remain high for many regional contexts. However, it is worth noting that although renewables provided (only) 23% of power generation worldwide by 2014, this share could reach 45% by 2030 with the rapid adoption of more ambitious plans and policies (IRENA, 2016).

The regional approach perhaps presents the biggest trade-off for analysts, policy makers and stakeholders in the world of energy. COETZEE and WINKLER (2014) and GARIBALDI *et al*. (2014) show how climate policies are very strongly linked to the idea of sovereign states (state-centered policies) in light of the concept of nationally appropriate mitigation actions (NAMAs) that arose in the context of the United Nations Framework Convention on Climate Change (UNFCCC) negotiations.

SANWAL (2010) and SCHÜLLER (2012) not only highlight the need to promote international cooperation, but also advocate that it should be rethought and based on institutions of supporting technology development and transfer. Thus, thinking about energy and climate policy at the regional level poses a huge challenge to policy makers, accustomed to doing so at the national level – although the gains associated with the implementation of such policies at the regional level are well-known (SANTOS, 2014, 2015, 2016, 2017).

Nonetheless, as well as the trade-off of renewable energies, cross-border pipelines and strategic transport channels, among other factors of increased complexity, can increase the risks and uncertainties of supply disruption due to (geo)political issues, wars, technical failures, accidents, geographic and geological catastrophes, extreme weather events and turbulence in financial markets (BIROL, 2006, CHESTER, 2010; KUCHARSKI and UNESAKI, 2015, UNDP, 2004, YERGIN, 2006). Precisely because of this, energy integration should be more than a simple arrangement of integrated energy markets and systems, but a political project with full participation of the involved parties in order to mitigate such risks and threats.

5.2 OSeMOSYS-SAMBA model

After analyzing the results of Mercosur (countries)'s energy policies during the period 1990-2010, 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[224]. In addition, as already highlighted, considering the regional energy integration, the power sector stands out, either by the possibility of improving the quality of life of the population, or by the previous expertise of most countries in the region in the matter.

Unlike the previous section, Bolivia and Venezuela are considered here. Both countries had to be removed from the previous section due to the absence of data for Venezuela (2013 onwards) and Bolivia (which only took place in 2015, after the SEES index).

The scenarios were modeled in the Open Source energy Modelling System – OSeMOSYS (2011) – using a new framework named South America Model Base – SAMBA (2015). OSeMOSYS-SAMBA provides long-term cost-optimization of the power expansion

[224] To access studies that consider other sectors, such as gas pipelines and oil, see CHÁVEZ-RODRÍGUEZ (2016), GARAFFA (2016), SABBATELLA (2015), SENA (2013), RODRIGUES (2012b), CUNHA (2010), LIZARAZU (2009) and KOZULJ (2006).

planning of South America countries. It is an open source, dynamic, bottom-up and multi-year power sector framework that allows us to deal with large-scale linear programming problems[225]. According to MOURA (2017), there was the following additions to OSeMOSYS to create SAMBA: '(1) storage constraints (WELSCH *et al.*, 2015); (2) reserve margins for each country (CERVIGNI *et al.*, 2015); and (3) annual constraints for production inflexibility applied to generation technologies, which was developed specifically for the implementation of SAMBA'.

As previously reported, data on existing regional infrastructure were used and the expansion plans of the countries. The base-year is 2013[226], with four scenarios built for the period 2013–2058. 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 not only because of the relationship with SEES index data, but because from that date we have to consider that the United Nations General Assembly unanimously declared the decade 2014-2024[227] 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.

Figure 22 shows how the model is structured into separate functions (blocks).

[225] The framework assumes an exogenously price-inelastic demand, perfect competition and perfect foresight (MOURA, 2017, MOURA *et al*., 2015).
[226]It gives full continuity to the analysis of section 5.1, although due to the lack of data for Venezuela the graphical analysis has only gone until 2010.
[227] See: http://www.se4all.org/decade.

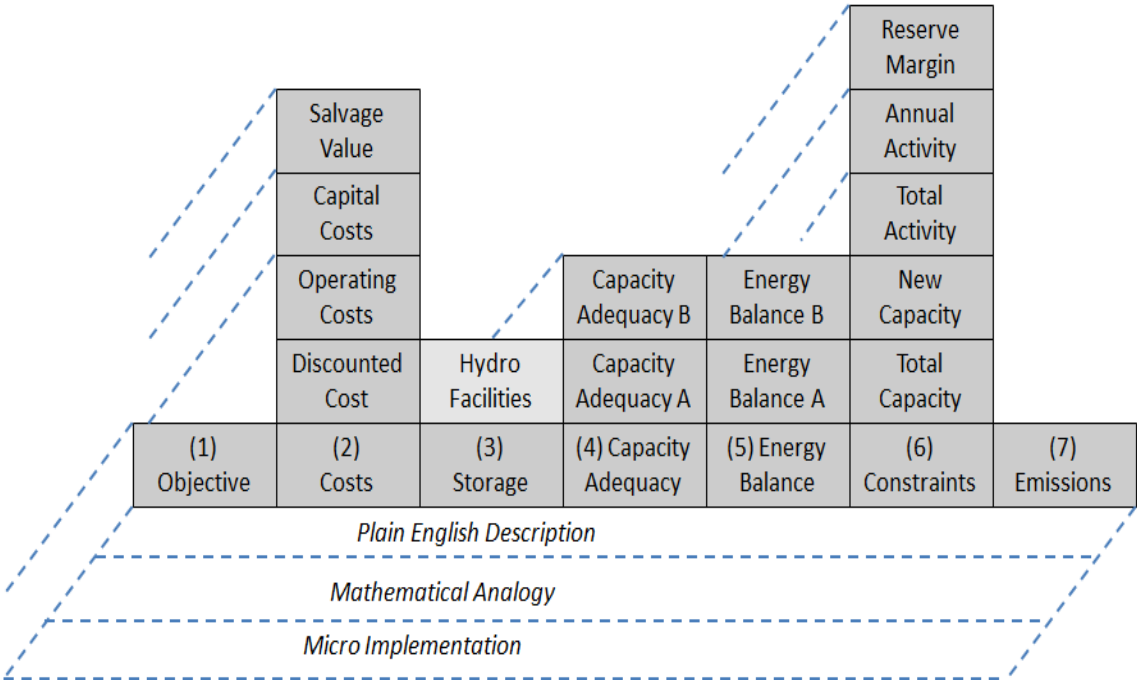

Figure 22. OSeMOSYS blocks structure

Source: HOWELLS *et al.* (2011).

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 in 34% by 2058 (IEA, 2014); (vii) subsidies in national fuel prices are eliminated in the long-term, allowing convergence to international prices; (viii) regarding losses in T&D systems, it is considered both reduction costs and increasing efficiency of generating technologies[228]; and (ix) existing oil refining capacity and international pipelines limit countries' national supply.

Besides, and according to MOURA (2017: 22):

> 'For all scenarios, the total electricity demand for each country is assumed to increase at an annual rate compatible to reach a per capita consumption of 5,500 kWh per year by 2058, which is comparable to the 2012 consumption level of developed countries such as Spain (5,530

[228] Losses in T&D reaches level of developed countries, between 6% and 8% in the long-term (IEA, 2012).

> kWh), Italy (5,515 kWh) and Greece (5,380 kWh) (WORLD BANK, 2015). This assumption aims at considering the social welfare gain arising from higher electricity consumption, given the disparities in electricity consumption in the continent.'

The availability of natural gas for electricity generation was restricted for SAMBA scenarios, then, producing and importing countries cannot use more than 50% of the extracted/imported resource in the power sector. Besides, 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.

Appendix G shows national and international inputs for all 10 countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Peru, Paraguay, Uruguay and Venezuela)[229] considered in OSeMOSYS-SAMBA scenarios.

As indicated in section 2.3.2, the profile of Latin American energy integration can be segmented into three blocks with particular characteristics. Generally, in the Central American region, there is an integrated dispatch, integrating several countries with low electric consumption in order to obtain an adequate scale, focusing basically on electrical integration. In the Andean Community, there is an international electricity transaction (EIT) dispatch, with countries having abundant energy resources. In the Southern Cone, energy transactions are contract-based, countries have high electricity consumption and

[229] Although the focus of the thesis and modeling are the Mercosur countries (Argentina, Bolivia, Brazil, Paraguay, Uruguay and Venezuela), it is important to highlight that it was necessary to analyze South America as a whole. This is because some Mercosur countries already have international interconnections and transactions with extra-bloc countries, as well as the fact that in the strong integration scenario (SIS), other extra-bloc countries will be taken into account.

there is abundance of energy resources (water and natural gas) and many international interconnections.

Thus, the few studies that have quantitative modeling in the Latin/South America region tend to focus on only one of these regional ‘blocks’[230]. An exponent in this theme is the publishing of the CIER 15 Project (Study of Electricity Transactions between Andean, Central American and Mercosur Markets: feasibility of their integration)[231], which was carried out in two parts. The participating countries were Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, Peru and Uruguay (Venezuela was not included). CIER carried out the project in consortium with PSR (Brazil), *Mercados Energéticos* (Argentina) and SYNEX (Chile), being funded by own resources, CAF and the World Bank.

The first part encompassed: (i) the elaboration of the historical and critical analysis of the existing interconnections (gas and electric power) and their evolution; (ii) the analysis of the regulatory and institutional evolution of the electricity and gas markets in each region; and (iii) the definition of scenarios for the development of secont part studies. The second part englobed: (i) the preparation of demand and supply energy studies for the Andean regions, in Central America and Mercosur, including gas and electric power over the 10-year horizon; (ii) the analysis and evolution of benefits and costs of the integrations and criteria and establishment for their proper attribution; and (iii) analysis of adequate regulatory and/or commercial schemes applicable to the Andean, Central American and Mercosur regions.

In its second part, the CIER 15 Project evaluated 12 projects, which involved the construction of approximately 10,000 km of transmission lines and 6,500 MW of installed generation capacity, requiring investments of US$ 5 billion. Its implementation resulted in a reduction of operating costs of US$ 1.5 billion per year, as well as avoiding the annual emission of 8 million tons of carbon into the atmosphere and increasing the security of the supply of the countries involved (CIER, 2011).

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

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[230] However, as has been pointed out a few times in this thesis, there is no pattern with respect to the countries participating in each of these 'blocs'. In some cases, it is considered Venezuela and/or Chile in Mercosur. IIRSA itself considers Chile in its Mercosur axis.

[231] See: http://www.cier.org/es-uy/Paginas/CIER-15.aspx.

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. All the measures of the four scenarios will be presented in detail and justified in subsection 5.2.1.

5.2.1 Assumptions

Similarly to selected projects by CIER Project 15[232], 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.

The **diversification of the power generation mix** is fundamental for the improvement of SEES index, mainly because it reduces the excessive dependence of fossil fuels, taking into account the environmental impacts. The rationale is to diversify into other domestic fuel types to stabilize prices at the pumps and at the same time meet carbon dioxide emissions limits (UNCTAD, 2010) (CIER, 2017c).

It is worth mentioning that the region of South America, and Latin America in general, has one of the cleanest power supply in the world. Therefore, the region's renewable energies enter the system based on their competitiveness rather than due to the need to make it cleaner (as in most countries). This reality distances the countries of the region from most IEA and OECD countries, for example.

Socio-environmental vulnerability will be considered in adopting physical limits, with the inclusion of maximum emissions quotas per period, as in MOURA (2017) and

[232] As well as the definition of the SEES index methodology, the presence of few quantitative studies on the region's energy policies suggests that the common bases are the same or similar. This allows, for example, comparisons between the results of these scarce studies. The choice of the OSeMOSYS-SAMBA model also has this objective, given the possibility of comparison with the recent scenarios and results of MOURA (2017).

CONDE (2013). Besides, it is included in the costs (model inputs), rather fixed (investment), variables or fuels, as well as the emission factors associated with each technology. This may have effects, for example, on the expansion of large hydroelectric dams, due to socio-environmental impact of their reservoirs, leading to an increase in the cost of new large hydro plants, postponement of the beginning of the operation or even unfeasibility.

The **increase of international transactions** in the elaboration of alternative scenarios will be considered, either by increasing power and/or new international interconnections, or by building new binational power plants. AALTO (2014), VON HIPPEL *et al*. (2011) and ECLAC (2007) highlight the relevance of interconnection infrastructure in regional integration, reinforcing the role of the regional institution/bloc in the supervision and promotion of this objective.

Focusing on the Latin American case, AHMED *et al*. (2017) and SAUMA *et al*. (2011) assessing ASEAN and CAN, respectively, highlight the need to enhance cross-border trade, arguing that the electric interconnection allows reducing the need for generation capacity reserves and, at the same time, providing a higher security level of supply. Moreover, an important benefit of electric interconnections is the potential contribution to reduce greenhouse gas emissions, given the better use of the resources of each country. In line with the criticisms of this thesis regarding state-centric energy policies, PUKA and SZULECKI (2014) propose an alternative approach to the discipline of energy economics to better understand the cross-border electricity infrastructure, defending the relevance of governance mechanisms, as well as political issues and discourses.

Specifically on the **harmonization of regulatory frameworks**, it was shown that it is fundamental to reduce the uncertainties and risks of governments and private investors in new regional ventures[233]. For this reason, it was necessary to analyze not only national policies and projects (**Chapter 3**), but also the general guidelines of Mercosur and UNASUR (**Chapter 4**) on the energy regulatory framework. Legal frameworks must be accompanied by dynamic regulatory frameworks capable of adapting to technological developments and market conditions (CAF, 2013b).

[233] It is worth highlighting the recent publication by PARLAMENTO ANDINO (2015), which highlights the need to deepen the process of harmonization of the regulatory and regulatory framework for sustainable energy.

Table 22 below presents general information for each of the scenarios modeled in OSeMOSYS-SAMBA.

Table 22. 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)
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: ENDE (2017), IPPSE (2017), MS (2017), LARREA *et al*. (2017), IMF (2016), YÉPEZ *et al*. (2016), COES-SINAC (2016), SOL.bo (2017), CIER (2017c), BERTERO (2015), KOUTOUDJIAN (2015), OLADE (2013), DAR (2011), National Expansion Plans, IIRSA, BN Americas, BID, FOCEM-Mercosur, ENDE, ENDE Andina, Hydro Review, Consulado de Bolivia, Siemens and BN Americas.

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)[234], in addition to 23 existing international interconnections (see first part of **Chapter 3**). 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. As highlighted in

[234] Despite RIS and WIS consider only Mercosur countries, in both MIS and SIS there are transactions between these countries and their neighbors (not only Mercosur States Parties, but also Associated States). Thus, it was necessary to consider national expansion plans projected by all South American countries (short, medium and long-term).

section 3.2, the country does not currently have energy interconnections with its neighbors, despite being in the center of the South American subcontinent.

In the last Bolivian national strategic plan 2017-2021, the international electrical integration has a weight of 15% (being only below the expansion and strengthening of the transmission network, 25%). The country highlights that of these 15%, the share for each country would be as follows: Argentina (80%), Paraguay (8%), Peru (7%) and Brazil (5%).

Table 23 highlights some of the events considered in the reference integration scenario (RIS).

Table 23. Reference integration scenario (RIS) detailed data

Country	Project	Investment (US$ millions)	Technology	Installed capacity	Year
Ar	Vaca Muerta (Neuquén)	40,000	Shale gas	55 MMm^3/day; 135 MMm^3/day; 270 MMm^3/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)	1,200	Natural gas	7 Mm^3/d (currently owns 4.7 Mm^3/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	1,140	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.

Regarding Argentina, the growth production of *Vaca Muerta* is considered, mainly located in the province of Neuquén, but also including the provinces of Río Negro, La Pampa and Mendoza. The cumulative investment in the period 2012-2020 will be US$ 40,000 million and the projected growth of shale gas production is 55 MMm^3/day (2020), 135 MMm^3/day (2025) and 270 MMm^3/day (2030), according to BERTERO (2015). Approximately 10% of this production is aimed at generating electricity.

It is worth mentioning that already in the reference scenario the possibility of energy swap between Argentina and Brazil is considered, using existing transmission lines at 500 kV of up to 2,000 MW. Electricity losses in transmission and distribution (T&D) are considered 15% (YÉPEZ *et al*., 2016).

In the case of Bolivia, new hydroelectric, thermal and solar PV plants are considered for domestic and export purposes. Among the hydropower projects, Miguillas, Misicuni, Ivirizu and San José stand out, most of them located in the Cochabamba department. The Miguillas hydroelectric power plant project is divided into hydroelectric power plants in cascade, located in the department of La Paz, has a total investment of US$ 448 million and a power of 203 MW. The first one, Miguillas 1 - Palillada, has an installed capacity of 118 MW and starts operating in 2019. The second one, Miguillas 2 - Umapalca, has an installed capacity of 85 MW and starts operating in 2022. The plant is in the Optimal Expansion Plan of the Bolivian National Interconnected System 2022 and has financing of the BCB (IMF, 2016).

The Misicuni hydroelectric plant is located in the department of Cochabamba and has a total investment of US$ 142 million. The financing of the plant came from the IDB and (Bolivian) National Treasury (TGN) (IMF, 2016). The dam has an installed capacity of 120 MW and starts operating in 2018. The Ivirizu hydroelectric plant is also located in the Cochabamba department and has a total investment of US$ 550 million. It has an installed capacity of 280 MW and it will start operating as early as 2022.

Like Miguillas, the San José hydroelectric project is also divided into two stages, totaling US$ 245 million and 124 MW of power. Project funding came from the IDB and CAF (IMF, 2016). It is also located in the Cochabamba department, the first phase has an installed capacity of 55 MW and starts operation in 2018, while the second has installed capacity of 69 MW and starts operation in 2019.

With regard to solar PV projects in progress in Bolivia, Solar Uyuni and Solar Yunchará stand out. The first one is located in the province of Potosí, has a total investment of US$ 94 million and a power of 60 MW. The financing of the plant came from BCB (IMF, 2016). The second PV plant is located in the province of Tarija, with a total investment of US$ 9.4 million (ten times lower) and a power of 5 MW (twelve times lower). Both projects go into operation in 2018.

Regarding thermal power plants, it should be noted that Siemens and ENDE Andina signed a Memorandum of Understanding (MoU) in November 2015. It will promote the expansion of the already existing Entre Ríos, Warnes and Del Sur thermal plants, all starting operating in 2020, totaling 480 MW each and with BCB financing (IMF, 2016). Entre Ríos thermal plant is located in Cochabamba department, has an investment of US$ 463 million and will have its installed capacity increased by 380 MW. Warnes thermal plant is located in Santa Cruz de la Sierra department, has an investment of US$ 406 million and will have its installed capacity increased by 320 MW. In addition, the Warnes thermal plant will have conversion from single cycle to combined cycle. Finally, Del Sur thermal plant is located in Tarija department, has an investment of US$ 463 million and will also have its installed capacity increased by 320 MW.

With regard to natural gas, Incahuasi Field is located in the municipality of Lagunillas, in Santa Cruz de la Sierra department, and has an investment of US$ 1,200 million, and reached a production capacity of 7 Mm^3/d (currently owns 4.7 Mm^3/d) in 2017. It is noteworthy that 90% of this production is aimed at exports to Argentina. Besides, electricity losses in T&D in Bolivia are 14% (YÉPEZ *et al*., 2016).

As for Brazil, we stress the construction of the international interconnection Presidente Médici (Br) - San Carlos (Uy), 420 km long and 500 kV HVDC back-to-back, due to the difference in frequency between both countries. The transmission line costs US$ 349 million, has a transmission capacity of 500 MW and has been operating since 2017. Electricity losses in T&D in Brazil are considered as 15%, same as Argentina (YÉPEZ *et al*., 2016).

In Paraguay, there will be two transmission lines Itaipu - Villa Hayes and Yacyretá - Villa Hayes, being only the first one considered in the RIS. The line is 348 km long, costs US$ 555 million, operates at 500kV, has a maximum transmission capacity of 1,200 MW and has been operating since the end of 2013. In the country, electricity losses in T&D are considered to be 27%, reaching 19% and 33% in Uruguay and Venezuela, respectively (YÉPEZ *et al*., 2016).

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[235]. 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. Besides, 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 households total, 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 to 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.[236] 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 conection to the desired harmonization of regional regulatory frameworks.

[235] Although they come from different reference scenarios, the measures implemented in the Weak Integration Scenario (WIS) are the same as the Alternative Trade Scenario (ATS) present in MOURA (2017).
[236] Thus, just like in the RIS, it is necessary to consider neighbors involved in these projects, taking the analysis to the countries of the Southern Cone. It is indirectly considered Chile and Peru (Mercosur Associated States since 1996 and 2003, respectively).

Table 24. 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	1,000	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)	2,300	Hydro	1,085 MW	2027
	Yacyretá - Itacorá-Itatí	6,000	Hydro	1,660 MW	2029
	Corpus Christi (Pindoí)	9,000	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.

The only countries that have strictly national projects are Bolivia and Paraguay (although with export purposes). As previously reported in WIS and section 3.3, Bolivia is not interconnected with any neighboring country, despite its five international borders (with Argentina, Chile, Brazil, Paraguay and Peru). In this sense, it is the country that has the greatest remaining potential to promote these regional initiatives, ratifying the national objective of making the country the regional export heart.

In Bolivia, the implementation of the El Bala hydroelectric plant, located on the Beni River, is considered. The construction of the plant will be divided into two stages, totaling 3,676 MW of power with a total cost of approximately US$ 6,920 million (total generation of 18,048 GWh/year). El Bala Componente 1 (Angosto Chepete 400) has 3,251 MW of installed capacity with reservoir, which at its peak extraordinary level would have an area of 680 km^2. Component 2 (Angosto El Bala 220), is run-of-river, with a capacity of 425 MW and is located 2.5 km downstream. This component will take advantage of the regulated and overflow waters of Component 1. The executing company of the project is ENDE, with its own resources (IMF, 2016). It is worth mentioning that the production of electricity will be mainly destined to be exported to the Brazilian market. Component 1 will start operating in 2030 and component 2 in 2043[237].

Finally, the last Bolivian hydroelectric plant considered in MIS is Rositas, whose investment will be approximately US$ 1 billion and installed capacity of 400 MW. The plant aims at supplying domestic demand, as well as exporting electricity to Brazil and Chile (through TL of 100 MW for each country), and starts operating in 2024. As it can be seen, Bolivia plays a fundamental role in this scenario, already having a series of projects and initiatives considered in the reference integration scenario (RIS). The country's goal is to create international interconnections with Argentina, Brazil, Peru and Paraguay totaling 1,359 km of extension. The total investment would reach US$ 622 million and the goal would be to export 8,000 MW to Brazil and 700 MW to Argentina[238].

Bolivia will also create international interconnections with Argentina, Peru and Chile. With Argentina, the interconnection will have 110 km to 500 kV, it will have a total cost of US$ 60 million and it will link the Yaguacua (Bo) - Tartagal (Ar) - San Juancito (Ar)

[237] Ende is studying a 615 km direct current transmission line from El Bala (Bo) to Montalvo (Pe), with an exchange of up to 1,000 MW. As they are only plans without major advances, this possibility was not incorporated in the scenario.
[238] In the model, the potential enters from 2020 to 100 MW each year.

regions. It has a maximum transmission capacity of 1,200 MW and it will start operating in 2019.

With Chile, the interconnection will have 150 km at 230 kV, total cost will be around US$ 60 million and it will connect the regions Punutuma (Bo) - San Cristóbal (Bo) - Laguna Colorada (Bo) - Radomiro Pomic (Cl). It has a maximum transmission capacity of 180 MW and it will start operating in 2021. We must consider the diplomatic problems between Bolivia and Chile due to the dispute over the exit to the sea. Anyway, even the CIER 15 Project affirmed that the project is broadly attractive for the interconnected system.

With Peru, two international interconnections are considered between the two countries[239]. The first of these links Azángaro (Pe) - Juliaca - Puno (Bo), has 114 km at 220 kV, with a capacity of 1,000 MW. The estimated cost of the project is US$ 81.3 million and will come into operation in 2021. The second links La Paz (Bo) - Puno (Pe), has 150 km at 230 kV, with a capacity of 150 MW. The estimated cost of the project is US$ 65 million and it enters into operation in 2022. In both cases it is necessary to have a back-to-back substation with converters, due to the difference in frequency between both systems.

As presented in RIS, Paraguay already has Itaipu - Villa Hayes line, but now the country will also create a Yacyretá - Villa Hayes interconnection. The transmission line has a length of 362.9 km, costs US$ 297 million, operates at 500kV, has a maximum transmission capacity of 300 MW and operates from 2019.

Argentina and Brazil will finally carry out the Garabí-Panambí binational hydroelectric complex, which totals 2,200 MW of installed capacity and starts operating in 2026. Garabí (quota 89) has a total investment of US$ 2,728 million, with 1,152 MW of power. Panambí (quota 130) has a total investment of US$ 2,474 million, with 1,048 MW. The construction of the plant is based on the Brazil-Argentina Treaty and its additional protocol, which make it possible to carry out hydroelectric studies in the Uruguay River region[240]. Both dams will be funded by the public sector of both countries, being part of

[239] It should be noted that in order to carry out the operational studies between Bolivia and Peru, there are difficulties in determining the price of gas that vary widely between both countries (CIER, 2013).
[240] See: http://eletrobras.com/pt/AreasdeAtuacao/geracao/garabi_panambi/Tratado_Brasil_Argentina.pdf.

the Growth Acceleration Program 2 (PAC 2) being financed by BNDES (UDAETA *et al*., 2016).

Yacyretá binational plant (Ar-Py) has four modifications to its initial project, which will increase its installed capacity by 3,480 MW. The first is the Aña Cuá branch, with an investment of US$ 610 million, contributing 270 MW and entering into operation in 2022. The second is the first expansion (Yacyretá 3), with an investment of US$ 100 million, contributing 465 MW and entering into operation in 2023. The third is the second expansion (Yacyretá 7), with an investment of US$ 2,300 million, contributing with 1,085 MW and entering into operation in 2027. The fourth change is Itacorá-Itatí, with an investment of US$ 6 billion, contributing with 1,660 MW and entering operation only in 2030

Argentina and Paraguay also have the entry of Corpus Christi, whose total investment will be US$ 9 billion and installed capacity of 3,500 MW (although there would be a viability of 3,400 MW). The Pindoí location alternative (km 1,658) rises with more possibilities due to less flooded territory and lower environmental effects (IPPSE, 2017).

As its name suggests, strong integration scenario (SIS) is the most audacious scenario. To be viable, there must be a series of changes, highlighted in section 2.3.1, 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 facing popular resistance to advance (Cachuela Esperanza), given their socio-environmental impacts. At the same time, swaps are considered between Paraguay, Argentina and Chile[241]. Finally, the scenario considers new international interconnections, with Chile, Ecuador and Peru.

[241] It should be noted that the reference integration scenario (RIS) already considers the possibility of electricity (or natural gas) swaps between Argentina and Chile, as well as between Argentina and Brazil. In the case of Chile, this mechanism occurred for the first time in October 2017, when Argentina sent 2 MMm^3 of natural gas to Chile, a volume that returned to the country in the same week. In December 2017, the ministers of energy of the two countries signed a bilateral agreement in Buenos Aires that will increase the energy exchange, both electricity and natural gas.

Table 25. Strong integration scenario (SIS) detailed data

Country	Project	Investment (US$ millions)	Technology	Installed capacity	Year
Bo-Br	Cachuela Esperanza (Beni)	2,460	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 (2017c), LARREA *et al*. (2017), COES-SINAC (2016), OLADE (2013), DAR (2011), IIRSA, BN Americas; * SINEA Project.

Cachuela Esperanza dam (Bo-Br interconnection) will cost US$ 2,460 million, will have 990 MW of installed capacity and will start operating in 2030. The plant will be located in the department of Beni, downstream of the Inambari project and its economic viability depends strongly on the construction of Cachuela Esperanza. Meanwhile, Cachuela Esperanza is located upstream of the Santo Antonio and Jirau plants in Brazil.

It is worth noting that Cachuela Esperanza is in the National Development Plan of Bolivia (PND), with the purpose of providing electrical power to the populations located in the far north of the country and at the same time promoting the development of the Bolivian Amazon. As the size of the plant is very large for the Bolivian system, much of its generation will be exported to Brazil.

However, Bolivia operates with frequency of 50 Hz and Brazil with 60 Hz, which requires converters in the project (increases its final cost). Therefore, there are two transmission lines between Bolivia and Brazil. One between Cachuela Esperanza (Bo) - Abuna (Br), of 105 km and with a transmission capacity of up to 200 MW. The other line from Cachuela Esperanza (Bo) - Porto Velho (Br), of 284 km through a double circuit of 500 kV, with an investment of US$ 792 million. The commercial and regulatory aspects between both countries must still be agreed, but being Cachuela Esperanza a run-of-river project, the operative agreements would be simpler (OLADE, 2013).

In the case of Cachuela Esperanza, public awareness of the importance of preserving the environment and respecting the rights and prerogatives of local communities, especially indigenous communities, is fundamental. An alternative to reservoirs would be to change the project into run-of-river, as they significantly reduce the flooded area, as well as socio-environmental impacts. This is particularly important for Brazil, since (i) the remaining hydroelectric potential of the country is concentrated mainly in the Amazon region, whose flat topography imposes a relation of flooded area/unfavorable energy generation; and (ii) the country generates more than two-thirds of its energy from hydroelectricity (BIATO, 2016). However, it is necessary to consider the side effect of the absence of reservoirs on the guarantee and stability of energy supply, especially if there is an impact and/or pressure on the construction of plants with reservoirs in neighboring countries in the border regions.

The Argentina-Paraguay-Brazil interconnection consists of constructing a 321 km long 500 kV line of 2,000 MW capacity, in Paraguayan territory, from Yacyretá to Itaipú. The link would allow optimizing the systems of the three countries besides Uruguay, which is interconnected with Argentina. Likewise, the probability of deficits in Brazil and Argentina would be reduced with a reduction in GHG emissions. This project is only in SIS because it would have to handle trade barriers linked to the Treaty of Itaipu (Br-Py), which did not allow the sale of energy to third countries (CAF, 2012). Therefore, it was considered that the project would only be carried out in 2030, since the discussions regarding Itaipu will only be clarified post-2023. It should be added that the problems of gas supply in Argentina are seasonal, due to the increased consumption for heating in winter (May to September), while in the same period the reservoirs in Brazil are full with some excess capacity for the system (OLADE, 2013). Here, there will be increased capacity for connections with Villa Hayes, which is considered in both reference integration scenario (RIS) and moderate integration scenario (MIS).

The energy swap between Paraguay, Argentina and Chile would allow the most efficient use of energy among the countries. The purpose of this interconnection is to send hydroelectric power from Paraguay to the northern region of Chile (SING)[242], where there is thermoelectric predominance. Given that Paraguay and Chile have no borders, the idea is that Paraguay would increase its energy dispatch by 200 MW for Argentina, through the binational Yacyretá plant, and Argentina in turn would send the same amount of 200 MW to Chile. It is worth adding that the Paraguay-Argentina swap does not require investments in new transport capacity.

The transmission lines would be as as follows: Yacyretá (Py) - Resistance (Ar) - Roque Sáenz Peña (Ar) - Monte Quemado (Ar) - Lumbreras/Cobos (Ar) - Atacama (Cl). The swap project between Paraguay, Argentina and Chile was one of the most attractive projects evaluated in CIER 15 Project, and it is a good example of the innovative use of optimizing the use of existing infrastructure (CIER, 2011). In order to implement this measure, a transmission line from Argentina to Chile with a capacity of 200 MW will be created in 2025.

[242] When it comes to Chile, it is important to stress that its reforms were implemented in the aftermath of the protracted reduction of the gas supply from Argentina (from 2004) and the 2010 earthquake, which disrupted energy supplies and electricity transmission. Between 2006 and 2008, gas imports fell by 88% as a result of a curtailment of gas supply from Argentina (IEA, 2018). In fact, the gas disruption from Argentina to Chile was one of the frequently cited emblematic cases of binational project/agreement risks.

The five interconnections below are part of the Andean Electric Interconnection System (SINEA)[243], which involves the CAN countries. It is necessary to consider this project in the SIS, even considering that on April 24, 2017, Decision N. 816 was published with the 'Regulatory framework for sub-regional interconnection of electrical systems and electricity exchange' among CAN countries. As such, they can be categorized in the following manner: (i) strengthening of existing interconnections; (ii) convenient interconnections to be developed in a bilateral scope; and (iii) convenient interconnections to be developed in a regional scope. SINEA gathers Chile, Colômbia, Equador e Peru, besides Bolivia as an observer (see section 3.2 and **Appendix E**).

Within the bilateral scope, previous studies evaluate that the following interconnection alternatives are economically feasible: Equador - Peru, Peru - Chile (both) and Chile - Bolivia. Ecuador - Peru and Ecuador - Colombia projects are not feasible bilaterally because the benefits of Ecuador would not be enough to offset the investment costs of this country (COES-SINAC, 2016). Anyway, in the strong integration scenario (SIS), all interconnections will be considered.

Colombia-Ecuador Interconnection is another project considered in the SIS. This interconnection is necessary to Ecuador, since the lack of investment in new generation capacity forced the country to use thermal power plants with high operating costs, which increased the marginal cost of the system, in addition to increasing the probability shortage. Colombia[244], for its part, has a greater diversity of generation sources (hydroelectricity, natural gas, coal and petroleum derivatives), so its marginal costs of the system were much lower than in Ecuador, thus creating favorable conditions for the exchange of energy between both countries (OLADE, 2013). The suggested interconnection links Alférez (Co) - Jamondino (Co) - Inga (Ec), has 505 km of extension

[243] In 2011, the Galapagos Declaration created the Council of Ministers of SINEA. The project seeks a feasible gradual advance with bilateral ties and has the proposed development of the Regional Electricity Market of SINEA countries (which would require changes/adjustments of regulations between countries). For this purpose, it suggests the following steps: (i) advance the regional electricity integration process with the Roadmap; (ii) advance bi-national electricity interconnections to achieve regional integration; and (iii) analyze and adopt regulatory harmonization agreement to confirm a regional electricity market in a gradual manner.

[244] Colombia signed a memorandum of understanding (MoU) with Australia that will allow the two nations to achieve greater cooperation between their respective hydrocarbon sectors. Additionally, the country signed a MoU with South Korea, which aims to implement a quality management system for liquid fuels in Colombia, as well as a tracking system for fuel performance and distribution of liquefied petroleum gas (LPG) (OLADE, 2017). It is then clear that Colombia has not been limited to the regional initiative to promote energy integration, but also promoted partnerships and cooperation with countries outside the region.

at 500 kV and maximum transmission capacity of 800 MW. It is scheduled to start operating in 2020.

Chile-Bolivia interconnection links Chuquicamata (Cl) - Laguna Colorada (Bo), having 140 km of extension to 220 kV. It has a maximum transmission capacity of 120 MW and is scheduled to start operating in 2020 (CIER, 2017c). Regarding the Peru-Ecuador interconnection, it should be noted that there is already an electricity interconnection between both countries of 100 MW, but it has not been able to be used due to regulatory problems and limitations of the transport systems. In addition, there is also an interconnection between Colombia and Ecuador, which is why operational studies must take into account the three systems together (OLADE, 2013). The proposed line connects La Niña (Pe) - Daule (Ec), has a length of 634.9 km at 500 kV. Its total cost will be US$ 522.25 million, with a maximum transmission capacity of 1,000 MW and an expected start-up in 2022.

There are two Peru-Chile interconnections. The first one interconnects Los Heroes (Pe) - Arica (Cl), it is a back-to-back connection of 220 kV and 70 km long. With a total investment of US$ 131.5 million, it has a maximum transmission capacity of 200 MW and is expected to start operating by 2020. The second interconnection links HVDC Montalvo (Pe) - Crucero (Cl) HVDC 500 kV, has 650 km in length and a total cost of US$ 989 million. Having a maximum transmission capacity of 1,000 MW, it is expected to start operating only in 2024.

It is important to consider that the modeling of the scenarios in OSeMOSYS-SAMBA presents some limitations. For energy modeling, there was difficulty in accessing certain data, particularly in the case of Venezuela. In addition, some countries did not have energy expansion plans.

Forecasts of all sorts are usually bad at predicting sudden changes (PALTSEV, 2016), and also difficult to make in the context of sudden changes. Consequently, it is worth highlighting the greater uncertainty regarding the scenarios due to the political-economic conjuncture that some countries face, particularly Brazil and Venezuela, as well as the possible change of political orientation in some countries of South America, with new presidential elections between 2018 and 2020.

From a modeling perspective, the ‘commoditization’ of international oil and liquid natural gas (LNG) prices also introduces a high degree of uncertainty in the planning of energy policy. The advance of LNG, in particular, may lead to a reduced need to build new gas pipelines in the region, which is the reason why they were neither considered in any of the scenarios, nor in the strong integration scenario (SIS). Another recent change in the energy market is the possibility of distributed generation, which is considered in the different scenarios mainly by the entry of solar photovoltaic generation in some countries. However, smart grids are not considered in the model.

Furthermore, due to modeling limitations, energy integration becomes an alternative to the need of having a complementary wind-solar-hydro energy matrix, as well as energy storage such as reversible hydropower, batteries, generators/fast-start engines, concentrated solar power (CSP) that accredits for the next 20 years (CIER, 2017b). Besides, to avoid discussions related to the food-water-energy nexus, it was assumed that only sugarcane was used for electricity generation, just like in MOURA (2017).

It is worth highlighting the methodological and operational challenge of increasing renewable energies, such as wind and PV, in energy systems, due to the great variability in the short and medium term. In addition, the large-scale location of the projects considered in the scenarios is far from the main demand centers, which would require extra reinforcements and investments in the transmission system (with the exception of distributed PV). Thus, seasonal wind-solar-hydric complementarity, storage, batteries and increased participation of intermittent renewables constitute technical-operational and regulatory difficulties that increase the need for adequate energy planning, demand management, as well as regulatory framework.

As for the scenarios themselves, it is necessary to consider some particularities. Due to the inability to predict what will happen with the renewal of GASBOL (2019) and the renegotiation of the Itaipu Treaty (2023), the reference integration scenario (RIS) has assumed that the relationship between the countries involved will remain partially the same, although Paraguay is bound to export less energy to Brazil at higher cost. It is assumed that, regarding GASBOL, prices will converge to international prices by 2058. Itaipu, in turn, will have its price increased until 2032, when it will converge to international prices.

The weak integration scenario (WIS) already considers the development of some LT and power plants in the region, since it is based on the reference integration scenario (RIS). Therefore, it also has measures to mitigate CO_2 emissions. However, the moderate integration scenario (MIS) can be considered reasonably optimistic, since it already considers certain projects whose popular resistance is significant, mainly due to socio-environmental impacts.

On the other hand, the strong integration scenario (SIS), as its name suggests, considers projects that seem unlikely to happen in the next 10-15 years. Precisely for this reason, SIS is the scenario that has fewer measures. Nevertheless, not even the SIS considers some plants that although announced, their negotiations seem to be paused as it is the case of certain plants in Bolivia and Peru (both for export to Brazil).

The binational Guajará-Mirim (Bo-Br) dam is one of the plants that were not considered. The project has 3,000 MW of installed capacity and costs about US$ 5 billion. It would also create a waterway network of 4,200 km navigable and stabilize the Jirau reservoir, adding 280 MW average generation. If the project were to advance, the objective of the Brazilian government would be to produce an agreement in accordance with the Itaipu Treaty. In 2016, Eletrobras and the Sustainable Consortium of Brazil (ESBR), which operates Jirau dam, signed memorandums of studies of the plant at the border with Bolivia. However, the only certainty of this venture up to date is its location. See **Appendix H**.

However, the region potentially affected by the project has low population density, both in Bolivia and Brazil, lacking in terms of basic services. In this context, such large infrastructure project could be conceived as the anchor project for the implementation of social and development policies in the region (CASTRO *et al.*, 2017).

The potential for bilateral integration between Peru and Brazil is immense, even though there are socio-environmental, geopolitical and institutional challenges (MOREIRA, 2016). However, Inambari dam was not considered even in the most optimistic scenario. The Inambari Dam (Pe-Br interconnection[245]) has an installed capacity of 2,200 MW, is located in the Peruvian Amazon (Cusco, Puno and Madre de Dios) and total cost of US$ 4,847 million[246]. Of that amount, around US$ 800 million corresponds to the transmission line with Brazil. It is located on the eastern slope of the Peruvian Andes, just 260 km

[245] The Agreement between Peru and Brazil with regard to the export of energy surpluses to Brazil, signed in June 2010, should be highlighted. See: http://www.minem.gob.pe/minem/archivos/file/Electricidad/acuerdo%20peru%20brasil%2016%20julio%202010.pdf.

[246] Both Brazil and Peru have a frequency of 60 Hz. The back-to-back converter is required for stability reasons (CAF, 2012).

away from the border with Brazil and therefore allows for the export of electricity to the country.

The plant would have a multiannual regulatory capacity reservoir and is located upstream of the Brazilian power stations of Santo Antonio and Jirau. Due to environmental restrictions, these two plants are run-of-river and the Inambari dam, when it is completed, would allow regulating the flows of the two plants mentioned on the Brazilian side of the basin, adding 90 MW of firm power to the system (DAR, 2011). Two alternatives are being studied to connect Inambari to the Brazilian electric system (SIN) but we rely rather on the possibility of constructing a 500 kV transmission line of 810 km that would connect it with the Madeira river plants in Brazil[247]. In modeling, it is planned to start operating in 2025.

It should be noted that Inambari would be the largest hydro in Peru and the fifth in Latin America. Notwithstanding, Peru has canceled the provisional license of the Inambari consortium (UDAETA *et al.*, 2016) due to: (i) massive rejection of the population; (ii) rejection by institutions such as the College of Engineers, Regional Government of Puno; (iii) rejection by the indigenous organizations and defense fronts that were constituted; and (iv) legislation that was not yet as aggressive as today's.[248] It is estimated that about 8,000 people will be affected by the project, which has a wetland area of 377.66 km^2, a reservoir with 319 km^2 of area.

Besides, the following hydroelectric plants with Peru were not considered: Sumabeni (1,740 MW), Tambo 40 (1,286 MW), Tambo 60 (580 MW), Paquitzapango (2,000 MW), Urubamba (940 MW), Vizcatán Mainique I (607 MW) and Cuquipampa (800 MW). Together, these plants would add approximately 9,000 MW of installed capacity (UDAETA *et al.*, 2016, DAR, 2011). The dams would be located in the Peruvian

[247] The proximity of Inambari to Brazilian cities such as Rio Branco and Porto Velho does not necessarily mean that interconnection costs with Brazil are going to be reduced, since the consumption of these cities is not enough to absorb the injected energy from Peru. Therefore, it would be necessary to transport the difference to the southeast region of Brazil, where the large cargo centers are located. One possibility will be to take advantage of the transmission infrastructure (HVDC lines with 2,500 km) that is being built to evacuate the energy produced by Santo Antônio and Jirau to the Southeast (CIER, 2012).

[248] See: https://ejatlas.org/conflict/represa-inambari.

Amazon, a region that already has a deficient electrical infrastructure, marked by the existence of national parks, indigenous societies and socio-environmental conflicts[249].

As regards the northern region of the South American subcontinent, it is noted that the Arco Norte famous project was not considered (see section 3.3 and **Appendix D**). In 2012, under Rio+20, it was defined that the project would contribute to LAC SE4ALL. In 2013, agencies, electricity companies, IDB and AFD formalized a MoU to study collaboration possibilities for electrical interconnection. Among the expected benefits of the initiative are: (i) increase energy security and reliability in electricity supply; (ii) reduce generation costs (enable large generating plants and reduce investments in reserve capacity); (iii) reduce dependence on oil (diversify the energy matrix of each country); and (iv) guarantee economic benefits (optimize electricity supply systems and provide lower rates to the final consumer).

With Brazil, there would be two international interconnections. The first one links Brazil (Roraima) - Guyana, which is expected to start operating in 2025. The second one would link (Brazil) Amapá - French Guiana and would be expected to start operations only in 2032. Both interconnections have capacity of a maximum transmission of 1,500 MW (LARREA *et al*., 2017). However, the logistical challenge of this project stands out given its geographical location. In addition, the OSeMOSYS-SAMBA model does not consider Guyana or French Guiana, which made it impossible to consider the Arco Norte Project in the scenario of more optimistic efforts towards integration.

5.2.2 Results

Moving on from the graphical analysis of section 5.1, which considered the period between 1990 and 2010 interspersed every five years, this subsection will provide an analysis with a planning horizon between 2015 and 2050[250], also following the same time

[249] It is important to consider other actors in this process, so as not to provide a naive analysis of the local reality. Therefore, more than just highlighting indigenous resistance, it is crucial to understand the weight of local economic groups that see these new projects as threatening competition for their plans and gains. There are even those who accuse such groups of financially supporting social groups and NGOs to create barriers to the advancement of these projects.

[250] The analyzes consider different 2050 pathways, as it has been done in different reports and scenarios, such as KPMG (2016), Europeam Comission (2016, 2011), Siemens (2014), UNCSD (2013), HONG *et al*. (2013), WEC (2016, 2013, 2007), IEA (2010, 2003) and Shell (2008), mainly when it comes to decabonizing electricity emissionsIt is important to note that although the SDG Agenda focuses on 2030,

interval of five years. In this way, this section will analyze each one of the four scenarios presented, carrying out a comparative analysis whenever it is possible and relevant. **Table 26** shows the evolution of installed capacity (GW) and generation (TWh) for each Mercosur country during the period 2015-2050.

Table 26. Evolution of RIS installed capacity and generation, by country (2015-2050)

Countries	**Installed capacity (GW)**					**Generation (TWh)**				
	2015	**2025**	**2035**	**2045**	**2050**	**2015**	**2025**	**2035**	**2045**	**2050**
Ar	15.8%	14.3%	18.4%	19.6%	20.5%	14.3%	15.2%	15.7%	16.1%	16.2%
Bo	1.0%	1.4%	2.2%	4.0%	4.4%	0.9%	1.4%	2.1%	3.1%	3.8%
Br	62.2%	65.1%	63.2%	62.4%	61.5%	62.4%	63.0%	63.3%	63.4%	63.3%
Py	4.2%	3.8%	3.0%	2.5%	2.7%	6.3%	4.8%	4.2%	3.6%	3.7%
Uy	1.5%	1.6%	1.3%	1.0%	0.9%	1.1%	1.2%	1.1%	1.0%	0.9%
Ve	15.2%	13.9%	12.0%	10.5%	9.9%	14.9%	14.4%	13.6%	12.7%	12.2%
Mercosur	**209.1**	**244.2**	**307.5**	**405.5**	**460.0**	**911.7**	**1,094.4**	**1,347.0**	**1,691.9**	**1,894.3**

Source: Own elaboration.

In the reference integration scenario (RIS), the participation of Brazil in terms of installed capacity, going from 130.1 GW (62.2%) in 2015 to 283.1 GW (61.5%) in 2050, is overwhelming (growth of 117.6%)[251]. Despite relative stability, Argentina (186.6%) and Bolivia (866.7%) expand their installed capacity further, while Paraguay, Uruguay and Venezuela lose relative weight.

In Argentina, installed capacity is growing mainly due to wind onshore (from 2027 on) and NGOC (from 2023 on, with Vaca Muerta), replacing the relevance of NGCC, which falls significantly. Also, less intense falls in the participation of heavy fuel oil (diesel and fuel oil) and large hydro take place.

the United Nations Sustainable Development Solutions Network (UNDSN) has already stated that SDG 13 (Climate Action) will need the development of deeper decarbonization pathways to 2050. Moreover, modeling framework is extended to 2058 in order to avoid so called ‘edge-effect’ considerations from affecting the reported results.

[251]Although this participation shows a slight tendency to fall in the other scenarios, it is possible to affirm that this pattern is based on the four scenarios analyzed.

Bolivia has increased installed capacity between 2015 (2.1 GW, 1.0%) and 2050 (20.3 GW, 4.4%) due to the expansion/creation of hydroelectric plants (Miguillas 1 and 2, Misicuni, Ivirizu, San José 1 and 2), solar plants (Solar Uyuni and Solar Yunchará) and thermal to combined cycle plants (CC Entre Ríos, CC de Warnes and CC Del Sur). This pressured the decline of NGOP and NGCC participation in the country, leading Bolivia to surpass Paraguay's installed capacity as early as 2039, reflecting national plans to make the country the region's energy exporter.

In Brazil, installed capacity is pressured by the increase in the share of wind onshore (from 2024 on), NGCC (from 2027 on), pulverized coal and the high (although with more stable growth) large hydro participation. By the way, large hydro has its proportion in national installed capacity reduced from 68.1% (2015) to 42.3% (2050).

Due to the significant weight of Itaipu in the installed capacity of Paraguay and Yacyretá (albeit to a lesser extent), Paraguayan installed capacity changed marginally in the analyzed period. There is participation of wind onshore (from 2044 on) and open cycle NG (only from 2047 on). There is an increase of 43.6% of national installed capacity between 2015 (8.8 GW, 4.2%) and 2050 (12.6 GW, 2.7%).

Similar to the Paraguayan case, Uruguay has a significant installed capacity based on Salto Grande (with Argentina) binational plants. A significant drop in the share of heavy fuel (from 2018) is compensated by increased biomass installed capacity (from 2020 on), wind onshore (from 2025 on), coal (from 2026 on) and small hydro[252] (from 2031 on). There is a 33.0% increase in national installed capacity between 2015 (3.2 GW, 1.5%) and 2050 (4.2 GW, 0.9%).

Venezuela also counts on the Guri dam installed capacity and sustained large hydro growth, especially after 2026, which replaces heavy fuel and NGOC. There was a 43.4% increase in national installed capacity between 2015 (31.9 GW, 15.2%) and 2050 (45.7 GW, 9.9%),

Indeed, the generation of each Mercosur country is in some way related to its installed capacity, as well as to the level of international insertion in terms of energy integration (number of international interconnections and binational plants). However, it is worth mentioning the small increase accumulated in installed capacity in Uruguay (33.0%) for

[252] Small hydro < 30 MW.

the period 2015-2050, which leads to an increase in the capacity factor of the country's plants (the same is true for Venezuela, because neither is involved in new projects in any of the four scenarios).

In Argentina, the generation from NGCC stands out, which falls in 2025 (although it remains significant until 2040). Wind onshore (from 2034 on) and large hydro (in a continuous way, with greater weight also from 2034 on) have significant and growing weight in Bolivia's electricity generation; this increase in generation replaces NGOC, small hydro and NGCC, falling to 7.0% (2050), 0.7% (2050) and 0.8% (2050) respectively.

In the case of Brazil, the weight of large hydro (including Belo Monte, Itaipu, Madeira and Tapajós) remains huge, despite its fall; it decreases to 47.4% (2050). The wind generation onshore, NGCC and coal generation grow to 15.2% (2050), 10.2% (2050) and 9.2% (2050), respectively. In Paraguay, the generation of Itaipu and Yacyretá hydroelectric plants accounts for 98.3% (2015) and 81.7% (2050), maintaining the country's generating matrix profile relatively stable (it loses prominency to wind onshore, especially as of 2045).

In Uruguay, generation from large hydro (including Salto Grande) is responsible for 63.3% (2015) and 38.3% (2050), being replaced by wind onshore, coal and biomass (in addition to wind offshore, from 2049 on). Finally, the generation of Venezuela is progressively replaced by large hydro, which surpasses 50% of the total generation as early as 2035. This hydro generation largely replaces generation from the NGOC.

In general, Mercosur's installed capacity increases by 120.0% between 2015 (209.1 GW) and 2050 (460.0 GW). The generation of Mercosur, in turn, increases 107.8% between 2015 (911.7 GW) and 2050 (1,894.3 GW).

Figure 23 shows the evolution of Mercosur's installed capacity by country in the period 2015-2050, in TWh. It can be seen that it falls in relation to the installed capacity of South America (SA), from 80.1% to 73.5%.

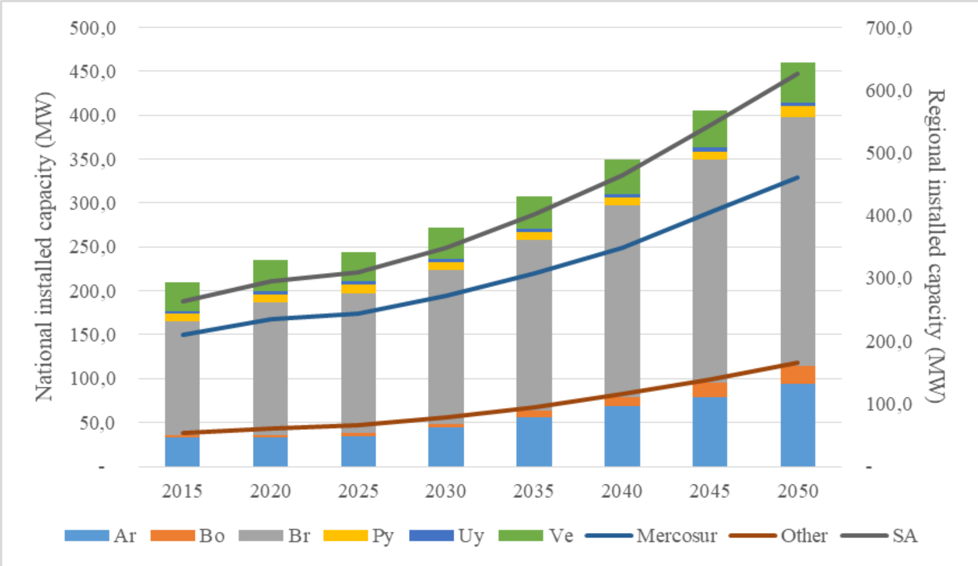


Figure 23. Evolution of RIS installed capacity (GW), by country (2015-2050)

Source: Own elaboration.

With the expansion of RIS installed capacity, an accumulated fall of 50.6% of the transactions through the TL between 2015 (43.2 TWh) and 2050 (21.3 TWh) is observed, leading to a fall in the capacity factor of TL between 2015 (4.7%) and 2050 (1.1%). This was due to the drop in transmission of energy from Paraguay to Brazil (by Itaipu). These results together confirm that making plans to expand installed capacity in the countries in a disjointed and disintegrated way leads not only to the need of greater investments in new plants, but also to the greater idleness of existing plants and TLs.

In the installed capacity shown by the weak integration scenario (WIS), similar to RIS, Brazil also stands out. Between 2015 and 2050, Argentina's installed capacity ranges from 33.1 GW (15.8%) to 94.9 GW (20.4%); of Bolivia, it goes from 2.1 GW (1.0%) to 20.3 GW (4.4%); in Brazil, from 130.1 GW (62.2%) to 288.7 (62.0%); in Paraguay, from 8.8 GW (4.2%) to 12.0 GW (2.6%); in Uruguay, from 3.2 GW (1.5%) to 4.2 GW (0.9%); finally, in Venezuela, installed capacity goes from 31.9 GW (15.3%) to 45.7 GW (9.8%).

The installed capacity of Argentina, Bolivia, Paraguay, Uruguay and Venezuela behaves similarly to RIS, since there are no alternative measures for these countries in the WIS. **Table 27** shows the evolution of installed capacity (GW) and generation (TWh) for each of the Mercosur countries in the period 2015-2050.

Table 27. Evolution of WIS installed capacity and generation, by country (2015-2050)

Countries	Installed capacity (GW)					Generation (TWh)				
	2015	**2025**	**2035**	**2045**	**2050**	**2015**	**2025**	**2035**	**2045**	**2050**
Ar	15.8%	14.6%	18.5%	19.4%	20.4%	14.3%	14.9%	15.5%	15.9%	16.1%
Bo	1.0%	1.4%	2.2%	3.9%	4.4%	0.9%	1.4%	2.1%	3.0%	3.7%
Br	62.2%	64.6%	63.3%	62.9%	62.0%	62.4%	63.7%	64.0%	64.2%	63.9%
Py	4.2%	3.8%	3.0%	2.4%	2.6%	6.3%	4.8%	4.1%	3.4%	3.4%
Uy	1.5%	1.6%	1.2%	1.0%	0.9%	1.1%	1.2%	1.0%	1.0%	0.9%
Ve	15.3%	13.9%	11.9%	10.3%	9.8%	14.9%	14.0%	13.3%	12.5%	12.0%
Mercosur	**209.1**	**242.9**	**309.7**	**410.5**	**465.7**	**911.7**	**1,128.1**	**1,380.1**	**1,723.4**	**1,926.4**

Source: Own elaboration.

In Brazil, the installed capacity of large hydro (including Belo Monte, Itaipu, Madeira and Tapajós) stands out (although it is decreasing), as well as the installed capacity of wind onshore, NGCC and biomass. As one of the alternative measures in the WIS is the increased installed capacity of distributed PV in all 4 subsystems of the country, it can be seen that it reaches 2.1 GW (1.2%) in 2030 and 8.8 GW (3.0%) in 2050. In terms of generation, this value increases to 5.2 TWh (2030), 11.2 TWh (2040) and 20.3 TWh (2050).

Another WIS alternative measure is the limit to expand large hydro in Brazil, which means that the reduction of generation hits a record of -14.3 TWh (2044) when compared to the generation of the same year in RIS. Finally, the last WIS particular measure considers lower investment costs of biogas (from second generation) power plants. This measure affects generation in Brazil (from 2041), reaching 5.7 GW (0.5% of total generation) in 2050.

Thus, Brazil is the only country that undergoes significant changes when compared to RIS, either in installed capacity or in generation. The drop in generation from large hydro is offset by increased biogas, biomass and NGCC generation. Relatively to RIS, the generation from biogas reaches 5.7 GW (2050); generation from biomass reaches 6.3 GW (2030), 5.7 GW (2040) and 16.7 GW (2050); in the case of NGCC, the generation grows 13.0 GW (2030), 10.8 GW (2040) and 5.7 GW (2050). It can be seen that the three alternative measures of the WIS led to greater diversification of Brazil's power generation mix (despite the greater increase in installed capacity) and total emissions.

Similar to RIS, Mercosur loses ground in South America both in terms of installed capacity and generation, mainly due to Colombia's growing weight in the regional energy scenario. Again, as in RIS, extra-Mercosur countries are not considered in the scenarios (only in MIS and WIS).

Therefore, regarding the nature of its alternative policies, WIS touches the: (i) diversification of the power generation; and (ii) consideration of socio-environmental vulnerability. However, in the face of a pessimistic scenario in terms of regional energy integration, what is observed in the Mercosur region is an increase in installed capacity of +3.7 GW (2040) and +5.7 GW (2050) and of generation of +33.7 TWh (2040) and +32.1 TWh (2050).

In addition, we can see the fall in transactions by TL in 2045 (-1 TWh, -5.0%) and 2050 (-4.1 TWh, -19.4%), leading to the fall in the capacity factor of TLs between 2015 (4.7%) and 2050 (0.9%). This was mainly due to the drop in energy transmission from Paraguay to Argentina (by Yacyretá) and to Brazil (by Itaipu), as well as from Brazil to Uruguay (TL Presidente Médice - San Carlos). These results together confirm what has been systematically defended throughout the thesis, that is, scenarios of less integration are less efficient from the point of view of investments in expanding regional installed capacity. Drawing a comparison with sections 2.1. and 4.2, in this scenario of less energy integration there would be greater interference when it comes to geography, in addition to probably greater socio-environmental impacts.

Moreover, it also indicates higher investment and operational costs. The former as a consequence of higher penetration of other renewables (non-hydro) technologies, such as photovoltaic distributed, and the latter due to higher fuel spending, as the NGCC plants become an important supply source (MOURA, 2017)[253].

Regarding the moderate integration scenario (MIS), it is noteworthy that installed capacity increases between 2015 (209.1 GW) and 2050 (455.7 GW). Despite this, the total installed capacity of MIS is lower in 2050 than WIS (-10.0 GW). **Table 28** shows the evolution of installed capacity (GW) and generation (TWh) for each of the Mercosur countries in the period 2015-2050.

[253] Similar to what happened in the Alternative Trade SAMBA (ATS), scenario of little integration proposed by MOURA (2017).

Table 28. Evolution of MIS installed capacity and generation, by country (2015-2050)

Countries	Installed capacity (GW)					Generation (TWh)				
	2015	**2025**	**2035**	**2045**	**2050**	**2015**	**2025**	**2035**	**2045**	**2050**
Ar	15.8%	14.2%	18.2%	20.1%	20.4%	14.3%	15.1%	14.5%	15.2%	15.5%
Bo	1.0%	1.9%	2.9%	3.5%	4.2%	0.9%	1.6%	2.4%	3.2%	3.9%
Br	62.2%	64.6%	60.9%	61.0%	61.0%	62.4%	62.8%	62.4%	62.8%	62.8%
Py	4.2%	3.9%	5.0%	3.8%	3.4%	6.3%	4.9%	6.1%	5.0%	4.6%
Uy	1.5%	1.6%	1.3%	1.0%	1.0%	1.1%	1.2%	1.1%	1.0%	0.9%
Ve	15.3%	13.8%	11.8%	10.5%	10.0%	14.9%	14.4%	13.6%	12.7%	12.2%
Mercosur	**209.1**	**244.5**	**311.8**	**403.6**	**455.7**	**911.7**	**1,095.4**	**1,349.9**	**1,693.2**	**1,896.2**

Source: Own elaboration.

In Argentina, the increase in installed capacity with the Garabí dam (1,152 MW, in 2016), Panambí (1,038 MW, in 2016), Yacyretá - 1st expansion (465 MW, in 2023), Yacyretá - 2nd expansion (1,085 MW, in 2027), Yacyretá - Itacorá-Itatí (1,660 MW, in 2029) and Corpus Christi (3,500 MW, in 2030), as well as NGOP (after 2032), is compensated by the decrease in installed capacity of wind onshore (after 2027), NGCC (after 2022), geothermal (between 2034-2043), coal (2040) and CSP (after 2046). In Bolivia, the installed capacity of MIS compared to RIS over the period falls. Although there has been a significant increase with the expansion and creation of new binational power plants, especially in the 2020s and early 2030s, and a modest increase in installed coal capacity (from 2040 onwards), it is offset by the sharp drop in installed wind capacity onshore from 2035 and timid geothermal fall.

In Brazil, the drop in installed capacity relative to RIS is significant especially since 2035, peaking in 2045 (-7.0 GW). In 2025, the strong increase in biomass and large hydro installed capacity overturns the installed capacity of wind onshore and thermals that use clean coal[254]. Paraguay's installed capacity is an exception, given the expansion of Yacyretá - Villa Hayes TL (300 MW in 2019), Yacyretá expansions (3,480 MW at the end of 2029) and the start of the Corpus operation (3,500 MW, in 2030).

[254] With carbon capture and storage (CCS).

Neither in Uruguay nor in Venezuela is there a significant change in the installed capacity of the plants compared to RIS. This is strongly due to the fact that neither country is involved in expansion projects in MIS.

Compared to WIS, Brazil's installed capacity fell further in 2030 (-230 MW), 2040 (-8.7 GW) and 2050 (-10.5 GW), peaking in 2045 (-12.2 GW). This is due not only to Garabí-Panambí dam (2,200 MW), but also to the fact that, unlike WIS, no 'alternative measures' are considered, which have led to the increase and diversification of installed capacity and the Brazilian power generation.

In terms of generation in the MIS, it grew by 108.0% between 2015 (911.7 TWh) and 2050 (1,896.2 TWh), with the participation of the generation of Bolivia and Paraguay in Mercosur. Although total generation relative to RIS falls to 2025, it grows up to 2050 (reaching maximum generation growth in 2041) due to new ventures particularly in Bolivia. The fall of generation in Argentina and Brazil is compensated by Paraguay, especially from 2035 on. Comparing the generation of the MIS with the one of the WIS, it is perceived that it is much lower in 2050 (-30.2 TWh).

Thus, regarding the nature of its alternative policies, MIS considers the first three: (i) diversification of the power generation mix; (ii) consideration of socio-environmental vulnerability; and (iii) (bi)national projects that increase international transactions. Unlike the WIS, increased integration between countries has led Mercosur to drop installed capacity of -1.9 GW (2045) and -4.4 GW (2050) against RIS. Compared to WIS, installed capacity fell -2.3 GW (2040), -7.0 GW (2045) and -10.0 GW (2050), while the generation drop was -28.8 TWh (2030), -31.1 TWh (2040) and -30.2 TWh (2050).

In addition, the increase in international transactions compared to RIS was observed through TL in 2030 (+10.8 TWh, + 34.1%), 2040 (+27.3 TWh, + 110.0%) and 2050 (+19.1 TWh, + 89.7%). This was mainly due to the increased transmission of energy from Paraguay to Argentina (by Yacyretá) and, more timidly, from Paraguay to Brazil (by Itaipu). Also noteworthy is the role played by the new TLs of Bolivia with Argentina, Chile and Peru, which start operating from 2020 and correspond to about 7.3% of the total transacted in all operation period. Again, these results confirm that more integration scenarios are more efficient because they require less installed capacity. In MIS, Paraguay owns special attention in terms of energy exports.

When it comes to the nature of its alternative policies, strong integration scenario (SIS) touchs all of them: (i) diversification of the power generation mix; (ii) consideration of socio-environmental vulnerability; (iii) (bi)national projects that increase international transactions; and (iv) harmonization of regional regulatory frameworks. In this way, installed capacity increases between 2015 (209.1 GW) and 2050 (453.7 GW), although to a lesser extent when compared to RIS.

Table 29 shows the evolution of installed capacity (GW) and generation (TWh) for each of the MERCOSUR countries in the period 2015-2050.

Table 29. Evolution of SIS installed capacity and generation, by country (2015-2050)

Countries	**Installed capacity (GW)**					**Generation (TWh)**				
	2015	**2025**	**2035**	**2045**	**2050**	**2015**	**2025**	**2035**	**2045**	**2050**
Ar	33.1	34.1	57.8	81.5	93.5	130.5	164.8	196.4	258.6	294.5
Bo	2.1	4.3	9.4	14.1	18.9	8.3	16.6	32.0	54.9	74.0
Br	130.1	157.9	188.2	243.9	275.6	568.9	688.6	840.2	1060.7	1189.7
Py	8.8	9.6	15.5	15.5	15.5	57.8	54.3	82.1	84.5	87.8
Uy	3.2	3.8	3.9	4.2	4.5	10.1	12.4	14.4	16.6	17.2
Ve	31.9	33.8	36.8	42.4	45.7	136.2	157.9	183.3	215.7	231.6
Mercosur	**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.

Unlike WIS, increased integration between countries[255] allows Mercosur to have a drop in installed capacity expansion of -3.8 GW (2045) and -6.3 GW (2050) compared to RIS. Compared to WIS, the installed capacity fell -8.9 GW (2045) and -12.0 GW (2050), while the generation drop was -28.8 TWh (2030), -30.3 TWh (2040) and -33.8 TWh (2050). Compared to MIS, the installed capacity fell by -1.4 GW (2040), -1.9 GW (2045) and -2.0 GW (2050), while the generation drop was -210 GWh (2030), -2.0 TWh (2040) and -2.2 TWh (2045).

In this way, and after presenting the results of all scenarios, the following tables and figures will provide a comparative analysis of total installed capacity (GW) and total

[255] South America as a whole, because in the SIS it is considered more than just the Mercosur countries.

(TWh) and technology generation, as well as electricity exchanges between countries (TWh)[256], share of international transmission lines in total generation (%), and total emissions (MtCO2e). **Table 30** below summarizes a comparative analysis between installed (GW) and generation (TWh) capacities of the four scenarios discussed.

Table 30. 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 24 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, as highlighted in section 2.3. Against the trend of MIS and SIS, there is an increasing trend in WIS installed capacity.

[256] It is important not to use the term 'trade' in this type of exchange, due to the peculiarities of of energy exchanges already highlighted.

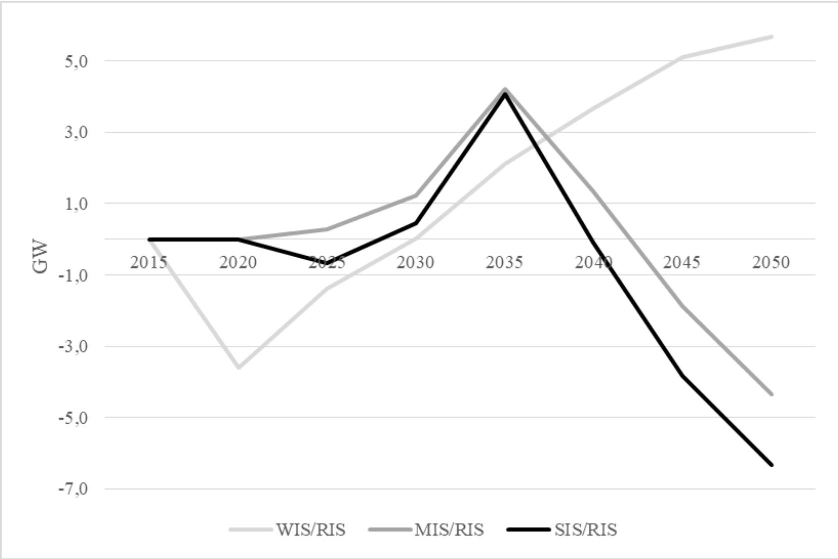


Figure 24. Comparative evolution of net installed capacity related to RIS, by scenario, in GW (2015-2050)

Source: Own elaboration.

Table 31 shows the installed capacity of Mercosur (GW) for each of the scenarios detailed by technology. Note the large and decreasing participation of large hydro, as well as the decrease of the participation of nuclear, diesel and fuel oil. On the other hand, NGCC, coal, CSP and wind onshore gain traction in the regional energy matrix.

Table 31. Installed capacity of alternative scenarios, by technology, in GW (2015-2050)

Technology	Installed capacity (GW)				
	2015	2050			
		RIS	WIS	MIS	SIS
Biogas	0.0%	0.0%	1.9%	0.0%	0.0%
Biomass*	4.8%	5.4%	5.9%	5.4%	5.5%
NGCC	6.2%	8.4%	8.6%	7.2%	6.8%
Clean coal	0.0%	0.0%	0.0%	0.0%	0.0%
Coal	1.8%	7.7%	7.2%	7.4%	7.6%
CSP	0.0%	4.4%	4.2%	3.8%	3.8%
Geothermal	0.0%	0.9%	0.9%	0.7%	0.7%
Diesel and fuel oil	7.5%	2.2%	1.5%	2.2%	2.0%
Nuclear	2.4%	0.3%	0.3%	0.3%	0.3%
NGOC	12.0%	4.9%	4.7%	5.8%	5.9%
PV	0.0%	0.1%	0.1%	0.1%	0.1%
Distributed PV	0.0%	0.0%	1.9%	0.0%	0.0%
Large hydro	64.8%	38.6%	36.0%	43.0%	43.2%
Small hydro	2.8%	2.1%	2.2%	2.2%	2.2%
Wind offshore	0.0%	0.0%	0.0%	0.1%	0.1%
Wind onshore	1.6%	24.7%	24.5%	21.8%	21.8%
Total	**209.1**	**460.0**	**465.7**	**455.7**	**453.7**

Source: own elaboration; * incineration.

It is worth noting the strong fall in the share of nuclear energy in Argentina and Brazil, which leads us to question the approval of nuclear projects in the two countries, either because of their real competitiveness or because of (geo)political decisions. In addition, the participation of coal (increase) and clean coal (decrease) is highlighted, which leads to the need to discuss the urgency to promote carbon-pricing instruments (carbon tax, cap-and-trade or mechanisms hybrids) in the region, which would favor generation from less carbon-intensive technologies.

Figure 25 does the same analysis of **Figure 24**, but based on the evolution of Mercosur generation (TWh). Again, the previous argument is ratified as it considerably increases the generation in WIS.

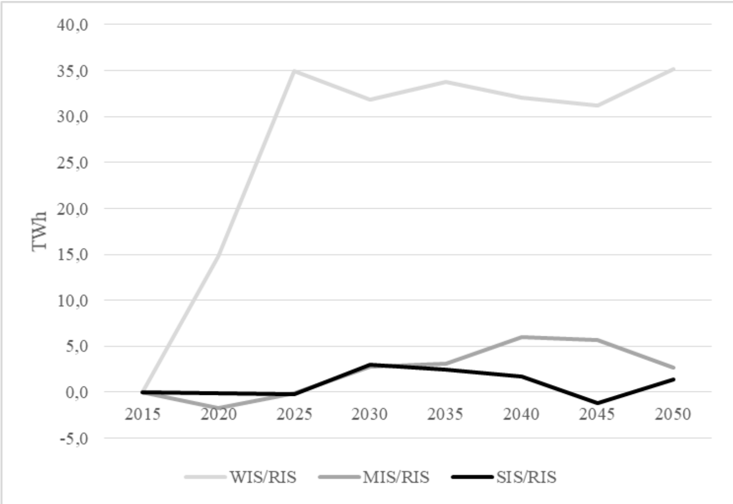


Figure 25. Comparative evolution of net generation related to RIS, by scenario, in TWh (2015-2050)

Source: Own elaboration.

Analogously to **Table 31**, **Table 32** shows the generation in Mercosur (TWh) for each of the scenarios detailed by technology. Note the constant participation of bagasse incineration plants. It is also noticed that despite the expansion and construction of hydroelectric plants, the participation of large hydro falls significantly in all scenarios.

Table 32. Generation from alternative scenarios, by technology, in GW (2015-2050)

Technology	Generation (TWh)				
	2015	2050			
	RIS	WIS	MIS	SIS	RIS
Biogas	0.0%	0.0%	0.3%	0.0%	0.0%
Biomass*	4.8%	7.5%	8.2%	7.6%	7.7%
NGCC	7.8%	7.6%	7.8%	6.5%	6.1%
Clean coal	0.0%	0.0%	0.0%	0.0%	0.0%
Coal	1.6%	9.1%	8.8%	8.7%	9.1%
CSP	0.0%	3.7%	3.6%	3.2%	3.2%
Geothermal	0.1%	1.6%	1.6%	1.1%	1.1%
Diesel and fuel oil	2.8%	0.1%	0.1%	0.1%	0.1%
Nuclear	2.4%	0.5%	0.5%	0.5%	0.5%
NGOC	6.3%	2.8%	2.7%	3.3%	3.3%
PV	0.0%	0.0%	0.0%	0.0%	0.0%
Distributed PV	0.0%	0.0%	1.1%	0.0%	0.0%
Large hydro	76.9%	45.6%	44.5%	49.8%	49.8%
Small hydro	2.5%	2.7%	2.8%	2.7%	2.7%
Wind offshore	0.0%	0.0%	0.0%	0.1%	0.1%
Wind onshore	1.2%	18.4%	18.1%	16.3%	16.3%
Total	**911.7**	**1894.3**	**1926.4**	**1896.2**	**1894.9**

Source: own elaboration; * incineration.

In addition, there is an increase in international transactions with respect to RIS through TL in 2030 (+11.4 TWh, +36.1%), 2040 (+27.3 TWh, +110.2%) and 2050 (+20.5 TWh, + 96.2%). This was mainly due to the increase in the energy transmission from Bolivia to Brazil, through Cachuela Esperanza (since 2030). However, the SINEA Project, despite its difficulties, has a marginal contribution to the installed capacity of South America (1.2% in 2050).

Table 33 shows the electricity exchanges in SIS between South American countries in 2050. Compared to **Table 4** (**Chapter 3**), it is possible to perceive not only the quantitative increase in energy exchange between countries, but also the new interconnections that operate in South America as a whole.

Table 33. Electricity exchanges in SIS between countries, in TWh (2050)

Country		Electricity exports (TWh)											
		Ar	**Bo**	**Br**	**Cl**	**Co**	**Ec**	**Pe**	**Py**	**Uy**	**Ve**	**Total imports**	**% imports**
Electricity imports (TWh)	**Ar**	-	0,0	0,0	0,0	0,0	0,0	0,0	20,7	0,0	0,0	20,7	49,4%
	Bo	0,0	-	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0%
	Br	0,6	2,0	-	0,0	0,0	0,0	1,4	13,5	0,2	0,1	17,9	42,7%
	Cl	0,3	0,1	0,0	-	0,0	0,0	0,0	0,0	0,0	0,0	0,4	0,9%
	Co	0,0	0,0	0,0	0,0	-	0,1	0,0	0,0	0,0	0,1	0,2	0,6%
	Ec	0,0	0,0	0,0	0,0	0,1	-	0,0	0,0	0,0	0,0	0,2	0,4%
	Pe	0,0	0,5	0,0	0,0	0,0	0,0	-	0,0	0,0	0,0	0,5	1,3%
	Py	0,0	0,0	0,0	0,0	0,0	0,0	0,0	-	0,0	0,0	0,0	0,0%
	Uy	0,9	0,0	0,9	0,0	0,0	0,0	0,0	0,0	-	0,0	1,9	4,4%
	Ve	0,0	0,0	0,0	0,0	0,1	0,0	0,0	0,0	0,0	-	0,1	0,2%
	Total exports	1,8	2,6	0,9	0,0	0,2	0,2	1,5	34,2	0,2	0,2	41,8	100,0%
	% exports	4,4%	6,2%	2,3%	0,0%	0,6%	0,4%	3,5%	81,7%	0,4%	0,6%	100,0%	

Source: own elaboration.

This is evident from **Figure 34**, which shows 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.

Table 34. Electricity exchanges in SIS between countries, in TWh (2050)

Scenarios	Transmission (TWh)					TL capacity factor (%)				
	2015	2025	2035	2045	2050	2015	2025	2035	2045	2050
RIS	43,2	32,4	28,2	20,5	21,3	4,7%	3,0%	2,1%	1,2%	1,1%
WIS	43,2	34,5	29,2	19,5	17,2	4,7%	3,1%	2,1%	1,1%	0,9%
MIS	43,2	36,6	55,9	46,5	40,4	4,7%	3,3%	4,1%	2,7%	2,1%
SIS	43,2	36,2	56,6	47,6	41,8	4,7%	3,3%	4,2%	2,8%	2,2%

Source: Own elaboration.

Figure 26 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.

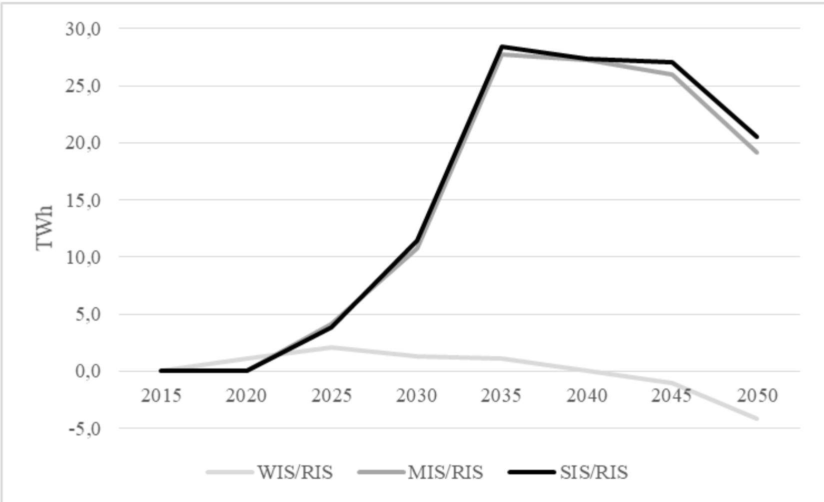


Figure 26. Comparative evolution of net electricity exchanges related to RIS, by scenario (2015-2050)

Source: Own elaboration.

With regard to emissions, **Figure 27** 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, in line with both the discussion in subsection 2.1.2 and section

5.1, 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 (WEC, 2017).

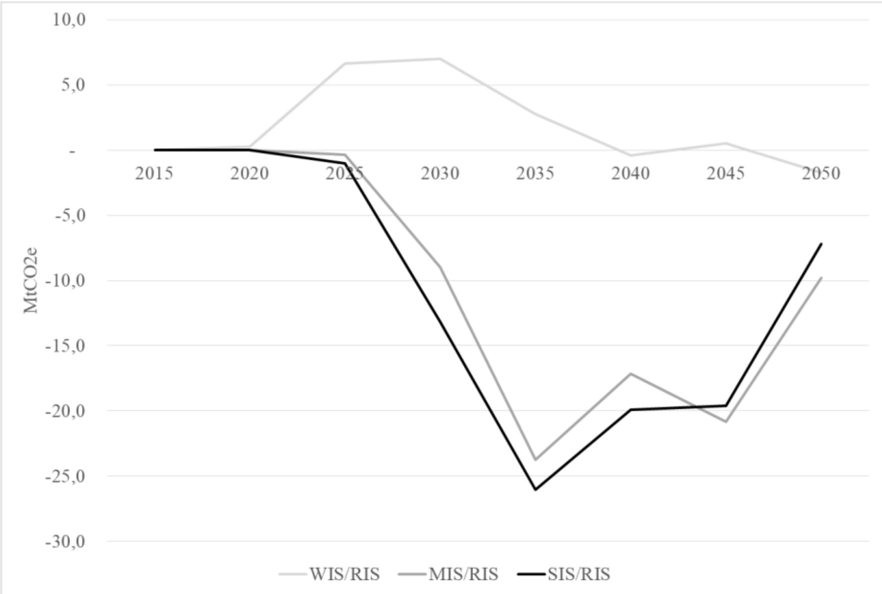


Figure 27. Comparative evolution of net emissions related to RIS, by scenario, in MtCO2e (2015-2050)

Source: Own elaboration.

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. 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.

6. Conclusions and recommendations

This thesis questions and challenges many issues and concepts assumed as true by the specialized literature, which, consequently, have impacts on the different decisions of policy makers. For this reason, it was necessary to carry out an extensive literature review to understand how the concept of energy security results abstract and vague (in the sense that it fits almost everything) and often ends up as instrument for specific and disconnected purposes. The idea is not to eliminate the concept nor to disregard its relevance, but to show its limitations and changes over the last decades. Therefore, the thesis proposes the concept of regional energy security, which incorporates more than one country in the analysis and, to achieve it in the context of South America (and Mercosur in particular), an essential tool is the regional energy integration.

In turn, regional integration is often divided into categories, such as economic/commercial, political and physical. Although this may make sense from a pedagogical and analytical point of view, we concluded that this has a very negative impact on the theory and practice of regional integration. This happens because energy integration, the cornerstone of this thesis, is often associated with physical integration, creating the illusion that it is therefore only a technical discussion. This subdivision into categories hides the interdisciplinary, transversal, dynamic and particular features of each experience, hindering dialogue beteen contributions from Economics, Politics, International Relations, Law, History and Geography, for instance.

When it specifically comes to energy integration, we conclude that the concept of integration, which is already used indiscriminately, becomes even more confusing. This is because (i) integration is not synonymous of neither trade nor cooperation; and (ii) in the energy world, there is a recent discussion of the integration of non-conventional renewable energy (NCRE). Thus, the discussion of energy integration becomes more heterogeneous and, therefore, less precise.

Another conclusion is that there is an extra blur when evaluating Mercosur, since there is no pattern for the countries analyzed: some studies only assess its original formation (Argentina, Brazil, Paraguay and Uruguay), others incorporate Chile, sometimes

Venezuela or even Bolivia. In general, the official formation of the bloc is not respected, what makes it even more difficult to understand the literature.

It has also been argued that studies of comparative regionalism are very common in the regional integration literature. While this may be interesting and positive, if it is not done with caution and care, the naive notion that there is an appropriate (single) path to follow would be reinforced, whether from the European (MIBEL and Nordpool), Asian (ASEAN) or Central America (SIEPAC) experiences as the only ways to be pursued by our regional energy initiatives. Therefore, we concluded that there are no one-size-fits-all solutions when it comes to regional integration, mainly when coping with energy integration.

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 for Brazil, in the case of Itaipu) created a bad and pessimistic history for the advancement of the process. In addition, the relative abundance of energy resources of the countries of the region does not push for integration, leading to (i) sub-optimal exploitation of these resources; (ii) overestimation of the need for investments; and (iii) underutilization of existing facilities and opportunities.

Brazil is often given the essential role in regional energy integration due to its expertise with SIN, since it borders ten countries in South America (except Chile and Ecuador) and because of its territorial extension. However, we established that Argentina and Bolivia have a central role in promoting regional energy integration. The fact that they have borders with five countries each, water resources in abundance, and large-scale conventional and non-conventional reserves places them in a strategic position in promoting regional (physical) energy integration. Peru also plays a significant role, particularly due to its borders with four countries in the region and an enormous hydroelectric potential available.

Although it is common in the literature, we should avoid proposals centered only on Brazil, using its neighbor countries as ‘annexes’ to supply its needs. Regional energy integration planning should be joint and participatory, taking into account the needs of the different countries involved in the process. On the other hand, the recent fact that Brazil does not have substantial threats to guarantee its energy supply, the discovery of the pre-salt, the economic viability of new energy sources and the reduction of national demand itself may help distort the trust other countries have placed in Brazil. In this way, the current moment is an ideal opportunity for Brazil to return to this regional agenda, although the conjunctural uncertainties make it difficult and delay this movement.

In general, it was possible to conclude that regional energy integration projects have been at the mercy of three main variables: (i) the famous (and old) dichotomy between government policy and State policy, which affects the support of certain interests in time (even by the lack of a solid project); (ii) the macroeconomic (inter)national context, which affects investment levels and priority agendas of these countries; and (iii) the asymmetric weight that projects play for the different countries involved, which affects the commitment and interest in making them regional realities. In addition, it was concluded that the institutional, regulatory and resource endowments structure between these countries is extremely diverse and, once again, asymmetric.

It was also established that a peculiar characteristic of Mercosur regional integration (and South American in a broader way) is the so-called presidential diplomacy, in which there is protagonist action of the heads of State in the definition of the objectives, principles and foundations. In this way, the progress of the process ends up being dependent (and vulnerable) to the domestic political situation/ideology of the countries of the region, making a sustainable long-term project impossible.

It was also showed the relative loss of participation of regional financing mechanisms, such as the IDB, CAF, FONPLATA, FOCEM and BNDES, in favor of China. From a geopolitical and geo-strategic point of view, this movement demands a prompt response from the countries of the region, either by the restoration of regional autonomy or by those who historically seek to represent regional leadership, as in the case of Brazil.

Added to this, in practice the normative effort of Mercosur and UNASUR was not able to overcome political, technical, economic and regulatory barriers that prevent the advance of energy integration in Mercosur countries. Due to the intergovernmental nature of both Mercosur and UNASUR, both institutions end up presenting limitations to their performance. Besides, SGT-9 did not act to structure and coordinate concrete policies or projects on regional energy integration.

Although Mercosur, through FOCEM, and UNASUR, through UNASUR-COSIPLAN, provide funds for projects in regional infrastructure, energy projects carried out by both institutions (i) are spatially concentrated in certain regions; (ii) are few (if compared to the total available value); and (iii) have been falling over time. As an adverse result, the region is experiencing not only the growth of Chinese influence, but the emergence of the Pacific Alliance (Colombia, Chile, Mexico and Peru), which sought to replicate this energy agenda on a more modest scale, seeking a true convergence of views between the countries involved. Moreover, the South American Energy Treaty seems very ambitious and therefore hard to move forward.

Thus, Mercosur's profile for the energy agenda has hitherto been based on simple bilateral energy trade agreements, energy interconnections for convenience and, at most, international (again binational) hydroelectric and/or gas pipelines, such as Itaipu, Yacyretá, Salto Grande and GASBOL. Ultimately, we concluded that there is no energy integration to date that (i) considers joint regional energy planning; (ii) is concerned with the harmonization of regulatory frameworks; and (iii) brings together producers, distributors and regional consumers in an integrated and participatory way.

When it comes to the current scenario, regional energy integration should be (re)thought considering renewable energies, given the wind, solar and hydro potential of the region. More than punctually integrated in an ad hoc manner, it should be optimized taking into account the complementarity of intermittent renewable sources, rainfall regimes and consumption (given the seasonality of demand, with tradeoff between use of air conditioning and heaters in the region). Therefore, we concluded that energy integration would be an alternative to the expansion of national networks, ensuring (i) the reduction of idle assets; (ii) less interference with geography and the environment; and, consequently, (iii) lower socio-environmental impact.

Considering the evolution of the SEES index for the period under analysis (1990-2010), it falls 8.9%. This suggests that the absence of joint planning and policies among Mercosur countries did not contribute to the improvement of the index, given the selected indicators.

Its is expected that the SEES index guides policy recommendations based on an indicator-based approach. By doing so, we can ensure a more holistic, intersectoral and appropriate approach to the subject. Thus, we established that the SEES index is completely in line with sustainable development and climate change considering a regional logic.

After evaluating the policies of the past until the present, the OSeMOSYS-SAMBA model was used to simulate scenarios of power sector integration in the region. As in the construction of the SEES index, the challenge was to deal with the lack of data and energy expansion plans in some countries. Undoubtedly, it will require *political will* and 'diplomatic engineering' to carry out the measures of each scenario in the face of such adverse political-economic context.

The modeling exercise ratified 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.

As seen, oil and natural gas play little role in modeled regional energy integration modeled. Oil is an international commodity, so it is difficult to provide regional contractual arrangements based on oil, either for priority sales or supply guarantee, when it is a type of energy whose price is defined internationally. With regard to natural gas, investment in physical pipeline infrastructure requires large amounts of capital, as well as specific, dedicated assets, having a sunk cost nature; like oil, LNG facilitates access to natural gas without necessarily needing pipeline networks. Both reasons do justify the relative loss of Venezuela's role in regional energy integration.

As a general challenge, the current context in which the Mercosur countries find themselves is characterized by stagnation and economic recession.

For the time being, the political context does not favor large long-term initiatives, since there is no convergence of strategic agendas between Mercosur countries. In addition, there is no short-term energy demand in Brazil that motivates investments in new power generation sources. The focus lies on Brazil, since both Eletrobras and BNDES have been key players in the elaboration and financing of regional energy projects. However, discussions about the privatization of Eletrobras is currently advancing and BNDES has recently reduced its disbursements. Once again, the events add uncertainty and insecurity to the scenario of regional energy integration.

Therefore, we need to take into account new actors and agendas, such as social, environmental, political-diplomatic, public opinion, human rights, local communities and organized civil society, in general, in the definition, implementation and realization of different international interconnection projects, as well as the construction of the new national, binational and/or multilateral plants. Energy, then, must be understood as a factor of socioeconomic development and, therefore, should aim at (i) promoting economic growth; (ii) universal access to safe, renewable and cheap energy; and (iii) to improve the quality of life, respecting environmental limits. In this sense, State plays a key role in conducting this process, so that it does not prioritize particular and/or exclusive objectives of big business owners, political lobbies and contractors. Private sector is also welcome to provide state-of-the-art projects and technologies and reducing financial burden on government budgets, alone or through public-private partnership (PPP).

Concerning the limitations of the study, it is particularly important to note the difficulty of finding some official national data and the energy modeling itself. One of them concerns the formulation of SEES index, particularly the relative weight of countries and indicators. In order to avoid overweighing one dimension against another, equal weight was given to all indicators in each of the three dimensions. The same happened with the weight of the countries analyzed, despite the existent asymmetry between them. For future work, the relative weight of each indicator/country should be detailed validated on a case-by-case basis.

Besides, a future challenge would be to expand the analysis of power sector integration towards other energy sources as oil and natural gas, and to other key demand sectors, as transportation. Although they were not the focus of the current analysis, these points deserve to be discussed in the near future.

Another limitation of this thesis, particularly regarding the integration scenarios analysis, is their vulnerability to the political-ideological and economic context of the countries of the region. As shown, the regional integration trend has been influenced by these issues for decades, which compromises the viability of the results presented in section 5.2.

Due to a series of assumptions, the intertemporal analysis may not consider eventual conjunctural changes in the region. As an example, the possible advance of carbon pricing instruments is not considered (for instance carbon tax, cap-and-trade or hybrid mechanisms), which would favor the generation from less carbon-intensive technologies. It is well known that some countries, such as Brazil, are analyzing implementation via

Partnership for Market Readiness (PMR), which will eventually influence future modeling results.

As recommendations for future work, we suggest updating the SEES index , especially because its results are very sensitive to the lack of data from some of the countries, englobing any of the selected indicators. In addition, it is suggested that it incorporates costs into the social dimension, as well as appropriate weights for each of the indicators considered.

Regarding the scenarios of the OSeMOSYS-SAMBA model, Guyana, French Guiana and Suriname should be also incorporated into the model in order to evaluate potential impacts of *Arco Norte* project on regional energy integration. Besides, it should incorporate other energy sources such as oil and natural gas, as well as key demand sectors like transportation.

Appendix A. Market Coupling Initiatives ordered by the degree of harmonization

Markets	**Participating countries**	**Degree of harmonization**	**Capacity Allocation Method**	**Capacity Calculation Method**	**Starting Date**	**Ending Date**
NPS	Norway, Sweden, Finland, Denmark and (Estonia since 10th May 2010)	High (Single PX)	Market splitting	ATC	1996	-
MIBEL	Spain and Portugal	High (Single PX, two divisions)	Market splitting	ATC	1st Jul. 2007	-
TLC	Belgium, France and the Netherlands	Medium (Separate PXs)	Price and Volume coupling	ATC	21st Nov. 2006	9th Nov. 2010
EMCC	Germany and Denmark (and Sweden)	Medium (Separate PXs)	(Tight) Volume coupling	ATC	9th Nov. 2009	9th Nov. 2010
CWE-MC	Belgium, Luxembourg, the Netherlands, Germany and France	Medium (Separate PXs)	Price and Volume coupling	ATC and Flow base	9th Nov. 2010	-

Source: Adapted from BAUMANN (2014), based on CRETI *et al.* (2010); NPS = Nord Pool Spot; MIBEL = Iberian Market; TLC = Trilateral Market Coupling; EMCC = European Market Coupling Company; CWE-MC = CWE Market Coupling; PX = Power Exchange; ATC = Available Transfer Capacity.

Appendix B. International interconnections in SIEPAC

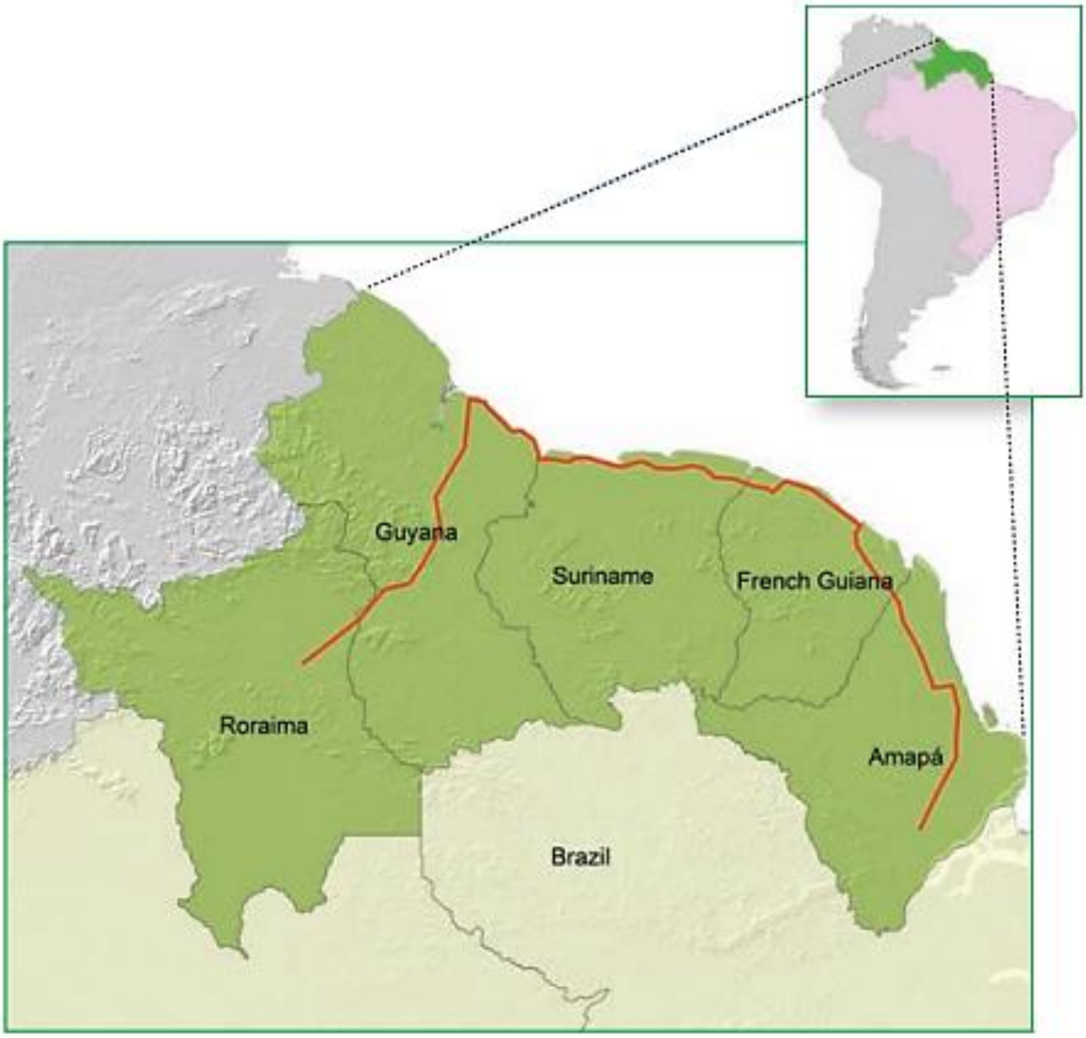
Ref.	Region / Countries	Place	Tension (kV)	Installed capacity (MW)	Status
1	SIEPAC	Sistema de Transmisión Regional (a)	230	300	Oper.
2	Gt-Mx	S.E. Brillantes (GT) – S.E. Tapachula (MX) (b)	400-230	200	Oper.
3	Co-Pa	Cerromatoso (CO) – Panamá (PA) (c)	-	400	Stud.

Source: CIER (2017b); (a) 1.800 km: 283 km in Guatemala, 286 km in El Salvador, 275 km in Honduras, 307 km in Nicaragua, 499 km in Costa Rica and 150 km in Panamá; (b) 101 km: 71 km in Guatemala and 30 km in Mexico; (c) 500 km: 220 km in Panamá, 130 km submarine, and 150 km in Colombia.

Appendix C. The GASBOL pipeline

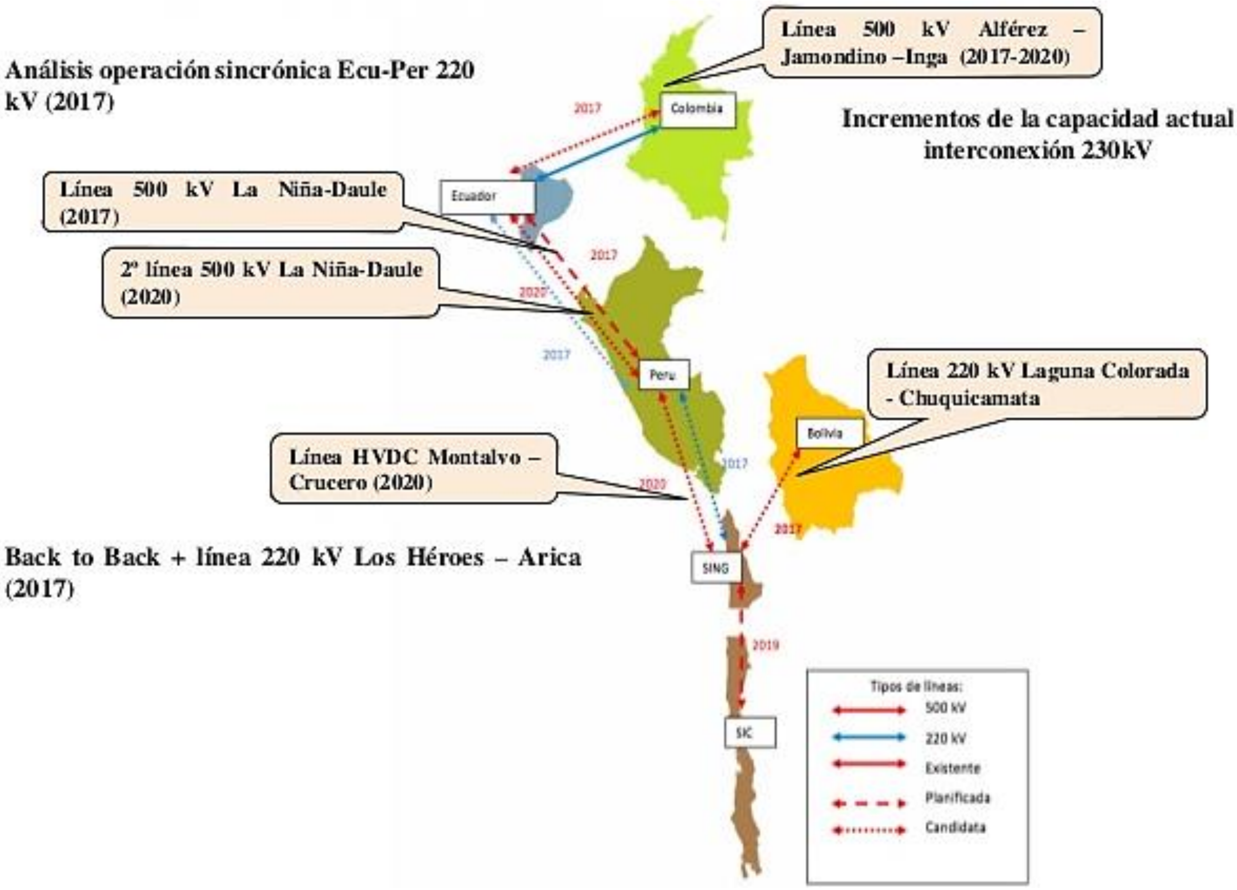
Source: Adapted from Gasnet.

Appendix D. The Arco Norte Project and proposed interconnection



Source: LARREA *et al*. (2017).

Appendix E. The SINEA Project and proposed interconnection



Source: OLADE (2016)

Appendix F. Structure of the South American Energy Treaty

Part I	Initial Provisions	Fundamental principles and commitments
		Definitions
		Goals
		Specific protocols
		Scope
Part II	Frameworks for Energy Integration	Chapter I: Energy Infrastructure
		Chapter II: Regulatory Frameworks
		Chapter III: Energy Security
		Chapter IV: Energy Exchanges
		Chapter V: Cooperation Mechanisms
		Chapter VI: Environmental Aspects
		Chapter VII: Investments
Part III	Institutional Provisions	Chapter I: The South American Energy Council
		Chapter II: Other institutional aspects
		Definitions of Additional Protocols of regional scope and partial scope
		Incorporation and deposit of the Additional Protocols
		Relationship between the Treaty and the Additional Protocols
Parte V	Dispute Resolution Mechanisms	
Part VI	General disposition	Relationship between this Treaty and other Regional and Bilateral International Agreements
		Transparency
Part VII: Final Provisions		

Source: Own elaboration based on AAS (2016).

Appendix G. National and international input data

National data come from: Argentina (MPF, 2013; CNEA, 2015a; CNEA, 2015b; CAMMESA, 2015a; CAMMESA, 2015b), Bolivia (AE, 2012a; AE, 2012b; AE, 2013; MHE, 2014), Brazil (EPE, 2012; EPE, 2013; EPE, 2014a; EPE, 2014b; EPE, 2015a; EPE, 2015b; ONS, 2014; ONS, 2015a; MME, 2006; MME, 2014), Chile (CDEC SING, 2012; CDEC SIC, 2013; MEN, 2014; MEN, 2015); Colombia (MME, 2011b; UPME, 2013; SIEL, 2015); Ecuador (MEER, 2012; CONELEC, 2013; ARCONEL, 2014a; ARCONEL, 2014b); Guyana (GPL, 2012); Paraguay (ANDE, 2015; VMME, 2014; VMME, 2015); Peru (MEM, 2014; COES SINAC, 2013; COES SINAC, 2015); Uruguay (DNE, 2013; ADME, 2015a; ADME, 2015b) and Venezuela (CNG, 2008; MPPEE, 2013a; MPPEE, 2013b; MPPEE, 2014; CORPOELEC, 2015).

Regional data come from *Síntesis Informativa Energética de los países de la CIER 2013* (CIER, 2013), *Panorama General del Sector Eléctrico en América Latina y Caribe* (OLADE, 2012), *Apuntes Sobre la Integración Elétrica Regional y Propuestas para Avanzar* (OLADE, 2013), *Potencial de Recursos Energéticos y Minerales em América del Sur* (UNASUR, 2013) and *Agenda de Proyectos Prioritarios de Integración* (IIRSA, 2015).

International data come from: WEO 2014 (IEA WEO, 2014), Energy Technologies Perspectives (ETP) (IEA WEO, 2012; IEA WEO, 2014; IEA WEO, 2015), ETSAP Technology Brief (IEA ETSAP, 2010a; IEA ETSAP, 2010b; IEA ETSAP, 2010c; IEA ETSAP, 2010d; IEA ETSAP, 2010e; IEA ETSAP, 2013a; IEA ETSAP, 2013b; IEA ETSAP, 2014), World Energy Perspective Cost of Energy Technologies (WEC, 2013) and World Bank (Word Bank, 2015). US EPA (2014), USGS (2006), US EIA (2015), US EPA (2014), WB Database, CEPALstat and UNdata.

The life span of each technology modeled in accordance with the Energy Technology Systems Analysis Program (ETSAP) Technology Brief reports (IEA ETSAP, 2010a; IEA ETSAP, 2010b; IEA ETSAP, 2010c; IEA ETSAP, 2010d; IEA ETSAP, 2010e; IEA ETSAP, 2013a; IEA ETSAP, 2013b; IEA ETSAP, 2014). For fossil fuel technologies, the thermal efficiency and its corresponding future improvements were obtained from the

Energy Technologies Perspectives report (IEA ETP, 2012; IEA ETP, 2014; IEA ETP, 2015).

The capital costs of each technology were identified from Energy Technologies Perspectives reports (IEA ETP, 2012; IEA ETP, 2014; IEA ETP, 2015) and World Energy Perspectives report (WEC, 2013). Capital costs of transmission lines were obtained from OLADE (2013) and IEA ETSAP (2014). Investment costs were estimated using the capital cost and a discount rate of 8% during the time period required to build each power project. The fixed and variable costs were obtained from (WEC, 2013) and (IEA ETSAP, 2010a; IEA ETSAP, 2010b; IEA ETSAP, 2010c; IEA ETSAP, 2010d; IEA ETSAP, 2010e; IEA ETSAP, 2013a; IEA ETSAP, 2013b; IEA ETSAP, 2014). For strategic hydro projects, the lowest cost available in literature for large hydro was considered. Finally, capital cost reductions over time were applied for each technology according to IEA ETP (2012), IEA ETP (2014) and IEA ETP (2015)[257].

[257] Except for the data in **Table 24**, it is important to highlight that the key assumptions of the RIS scenario are the same as those of the RTS scenario presented in MOURA (2017). This is justified by the fact that both models are based on the analysis of the energy integration of (of part) South America countries, assuming 2013 as a base-year.

Table G.1. Generation Input Data in 2013

Techologies	Investment Cost (US$/kW)	Fixed Cost (US$/kW)	Variable Cost (US$/GJ)	Inflexibility* (% of instaled capacity)	Capacity factor (%)	Efficiency (%)	Expected lifetime (years)	Construction time (years)
Biogas	2,449	50	1.8	34	85	40	25	4
Biomass incineration	1,905	13	0.5	34	66	35	25	4
Coal pulverized	3,129	44	1	45	85	45	40	4
Coal with CCS	6,530	102	1	45	85	40	40	4
CSP	4,914	65	1.7	0	40	35	40	1
PV	1,944	40	0	0	25	25	25	1
Distributed PV	3,000	40	0	0	32	25	25	1
Fuel oil	1,400	25	1.7	27	85	35	25	2
Geothermal	3,966	120	0	0	85	15	20	2
Hydro large	2,939	45	1	13	n.a.	100	60	5
Hydro small	3,499	35	1	13	n.a.	100	60	2
Hydro large (strategic)	2,351	26	0	13	n.a.	100	60	5
NGCC	1,260	20	2.5	42	85	57	30	3
NGOC	583	10	2.5	27	85	38	30	2
Nuclear	7,200	115	3.1	50	85	35	40	5
Wind onshore	4,104	114	0	0	42	100	25	1
Wind offshore	1,620	36	0	0	31	100	30	1
Distribution lines	**1,491**	**0**	**0**	**n.a.**	**n.a.**	**75-95**	**60**	**1**
Transmission lines	**746**	**0**	**0**	**n.a.**	**n.a.**	**93-96**	**60**	**1**
Transmission subsystems	**448**	**0**	**0**	**n.a.**	**n.a.**	**93-96**	**60**	**1**

Source: based on (MOURA, 2017, IEA ETSAP, 2010a; IEA ETSAP, 2010b; IEA ETSAP, 2010c; IEA ETSAP, 2010d; IEA ETSAP, 2010e; IEA ETSAP, 2013a; IEA ETSAP, 2013b; IEA ETSAP, 2014; IEA ETP, 2012; IEA ETP, 2014; IEA ETP, 2015).

Table G.2. Generation Input Data in 2058

Techologies	Investment Cost (US$/kW)	Fixed Cost (US$/kW)	Variable Cost (US$/GJ)	Inflexibility* (% of instaled capacity)	Capacity factor (%)	Efficiency (%)	Expected lifetime (years)	Construction time (years)
Biogas	1,905	50	1.8	34	85	40	25	4
Biomass incineration	1,905	13	0.5	34	66	35	25	4
Coal pulverized	2,313	44	1	45	85	52	40	4
Coal with CCS	4,626	102	1	45	85	44	40	4
CSP	2,160	65	1.7	0	40	35	40	1
PV	972	40	0	0	25	25	25	1
Distributed PV	1,000	40	0	0	32	25	25	1
Fuel oil	1,400	25	1.7	27	85	35	25	2
Geothermal	2,508	120	0	0	85	15	20	2
Hydro large	2,939	45	1	13	n.a.	100	60	5
Hydro small	3,499	35	1	13	n.a.	100	60	2
Hydro large (strategic)	2,351	26	0	13	n.a.	100	60	5
NGCC	1,260	20	2.5	42	85	62	30	3
NGOC	583	10	2.5	27	85	42	30	2
Nuclear	6,318	115	3.1	50	85	37	40	5
Wind onshore	1,592	114	0	0	42	100	25	1
Wind offshore	1,296	36	0	0	31	100	30	1
Distribution lines	**1,491**	**0**	**0**	**n.a.**	**n.a.**	**94-97**	**60**	**1**
Transmission lines	**746**	**0**	**0**	**n.a.**	**n.a.**	**95-97**	**60**	**1**
Transmission subsystems	**448**	**0**	**0**	**n.a.**	**n.a.**	**95-97**	**60**	**1**

Source: based on (MOURA, 2017, IEA ETSAP, 2010a; IEA ETSAP, 2010b; IEA ETSAP, 2010c; IEA ETSAP, 2010d; IEA ETSAP, 2010e; IEA ETSAP, 2013a; IEA ETSAP, 2013b; IEA ETSAP, 2014; IEA ETP, 2012; IEA ETP, 2014; IEA ETP, 2015)

Appendix H. Location of the Madeira River dams

Source: Observatório Ambiental Jirau

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