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Energy Security Index in South America - A Sustainable Approach

Dissertação de Mestrado em Energy para Sustentabilidade, orientada por
Profª Drª Patrícia Pereira da Silva e Profº Drº Pedro André Cerqueira e apresentada à
Faculdade de Ciências e Tecnologia de Coimbra

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UNIVERSIDADE DE COIMBRA

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A Sustainable Approach

Dissertação de Mestrado em Energia para Sustentabilidade, apresentada à

Faculdade de Ciências e Tecnologia para obtenção do grau de Mestre

Profª Drª Patrícia Pereira da Silva
Profº Drº Pedro André Cerqueira

Coimbra, 2018

Dedicatory

To Marize and Volney.

Acknowledgments

I would like to express my sincere gratitude to my supervisors Profª Drª Patrícia Pereira da Silva and Prof Dr Pedro André Cerqueira, for giving me autonomy to develop my work but always with continuous support, patience, motivation and immense knowledge.

I thank my fellow flatmates for feeding me and for the endless companionship in all moments.

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Last but not the least; I would like to thank my family for all the love.

Resumo

O nível de desempenho de um sistema de energia de um país, ou região, pode ser avaliado de acordo com diferentes metodologias de índices. A literatura apresenta uma grande variedade de dimensões e métricas que conseguem ser aplicadas para estimar a segurança energética. Além disso, o conceito de segurança energética aceita diferentes premissas, influenciando a definição das dimensões a serem aplicadas. Um índice de segurança energética que permita a análise detalhada de cada dimensão e premissa pode ser utilizado como uma importante ferramenta nos processos de elaboração de políticas de energia.

A América do Sul possui importante papel na geração e fornecimento de energia no cenário mundial, influenciando os níveis de segurança energética globais. Estudos de segurança energética na América do Sul estão especialmente relacionados com a integração dos sistemas de transmissão e distribuição entre os países.

Neste trabalho desenvolveu-se uma metodologia adaptada do *Energy Trilemma Index*, criado pelo World Energy Council, para classificar dez países Sul Americanos de acordo com suas pontuações no período entre 1994 e 2015. Igualmente, este estudo avaliou a evolução de cada país, comparada com seu próprio desempenho em 1994. Traçou-se uma evolução cronológica relacionada aos principais resultados, de forma a contextualizá-los ao período econômico e político. Uma segunda comparação foi realizada entre a América do Sul e os dez melhores países classificados no relatório de 2016 do *Energy Trilemma Index*. As diferenças entre cada dimensão da segurança energética foram identificadas e políticas de energia do melhor país foram pesquisadas para serem utilizadas como *benchmark*.

Esta dissertação conclui que a segurança energética na região vem melhorando nos últimos anos, impulsionada principalmente pelo aumento no acesso da população à eletricidade, pela diminuição nas importações de energia e pela diversificação da matriz energética. Chile e Argentina são os países com melhores índices, enquanto a Bolívia foi o país que mais melhorou o desempenho no período. Em comparação com os dez melhores países, como esperado, a América do Sul ficou em último lugar em todos os anos, principalmente devido aos seus baixos índices de acesso à eletricidade, eficiência energética e contexto político e econômico.

Palavras-chave: segurança energética; América do Sul; índice de segurança energética; sustentabilidade; dimensões da segurança energética.

ABSTRACT

The energy system performance level of a country or region can be accessed according to different indexes' methodologies. The literature shows a wide range of dimensions and metrics that can be applied to evaluate the energy security. Also, the energy security concept accepts different assumptions, influencing the dimensions analyzed through the application of indexes. An energy security index that permits the detailed analysis of each dimension and metrics can be used as an important tool in energy policy-making processes.

South America plays an important role in the energy generation and supply in world scenario, influencing global energy security levels. To the best of our knowledge, energy security studies applied to South America are specially related to the integration of transmission and distribution systems between countries.

This work developed a methodology adapted from the Energy Trilemma Index, created by World Energy Council, to rank ten South American countries according to their energy security scores in the period between 1994 and 2015. Equally, this study evaluated the evolution of each country, compared to its own performance in 1994. A chronological evolution was related to the main results, in order to contextualize them to the economic and political period.

A second comparison was made between South America and the ten best countries ranked by the Energy Trilemma Report 2016. The differences among each energy security dimensions were appointed and energy policies in the best country were surveyed to be used as benchmark.

This dissertation concluded that the energy security in the region has been improving in the last years, driven by the increase in the electricity access, by the reduction in energy imports and by the diversification of energy mix. Chile and Argentina were the countries with the best indexes, whilst Bolivia was the country that most improved the performance. Comparing to the top ten countries, South America always ranked in the last position, as expected. It was mainly due to the low levels of electricity access, energy efficiency and country context.

Keywords: energy security; South America; energy security index; sustainability; energy security dimensions.

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List of abbreviations

Arg	Argentina
Aus	Austria
Bol	Bolivia
Bra	Brazil
Chi	Chile
Col	Colombia
Den	Denmark
EAPI	Energy Architecture Performance Index
Ecu	Ecuador
EIA	Energy Information Administration
ESI	Energy Security Index
EU	European Union
FDI	Foreing Direct Investment
Fin	Finland
Fran	France
GDP	Gross Domestic Product
Ger	Germany
GHG	Green House Gas
HHI	Hernfindahl-Hirschman Index
IEA	International Energy Agency
Nor	Norway
Nth	Netherlands
Nze	New Zealand
OECD	Organization for Economic Co-operation and Development
OLADE	Organización LatinoAmericana de Energía
OPEC	Organization of the Petroleum Exporting Countries
Par	Paraguay
Per	Peru
RD&D	Research, Development and Deployment
SA	South America
Swd	Sweden
Swz	Switzerland
T&D	Transmission and Distribution
U.S.	United States
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
Uru	Uruguay
Ven	Venezuela
WEC	World Energy Council
WEF	World Energy Forum

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INTRODUCTION

Energy security was first discussed at the beginning of 20th century due to the oil crisis, in the 1970's, reappearing in 2000's "driven by rising demand in Asia, disruption of gas supplies in Europe, and the pressure to de-carbonize energy systems" (Cherp & Jewell, 2014, p. 415). Early conceptualization only related to stability of oil prices. Contemporary concepts, however, address broader issues of energy policy, as the equal access to energy and environmental concerns, as climate change.

Knowing the energy security level of a country or region is important for the development and implementation of energy policies. Bompard et.al (2017) argued that scientific models should be applied in energy security assessments in order to provide detailed information and quantitative indexes to policy makers. In addition, these models allow better understanding of the relevance of energy demand, threats, vulnerabilities and conflicts in the development of a country from different dimensions - political, military, economic and socio-environmental (Silva H. I., 2015).

The performance of the energy system of a country or region can be accessed according to different indexes. The literature shows a wide range of dimensions and metrics that can be applied to evaluate the energy security. Also, energy security is a concept with different assumptions, influencing the dimensions analyzed through the application of these indexes. The development and deployment of an energy security index might enable the definition of energy policies, as it can demonstrate the indicators and parameters with greater influence in the reliability of the energy system, either security of supply, equity of supply or share of renewables, among other issues.

This study adapted the *Energy Trilemma Index* methodology to measure the energy security considering sustainable assumptions, dealing with social, economic and environmental indicators in ten South American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay and Venezuela. The energy security performance was evaluated in the period between 1994 and 2015.

The next chapter presents the diversity of energy security concepts and assumptions considered for each of them. This survey guided the definition of which, among the existing assessment methodologies, is the one chosen for this study. Also in chapter 2, the most relevant existing indexes that inform the energy security level of a country or region are discussed in details.

The methodology for the selection and calculation of the index is discussed in chapter three.

The results are presented in chapter four. First the aggregated results for South America are discussed. The best and worst countries are ranked from 1994 until 2015, and the performance of security's dimensions is analyzed. After, the evaluation is conducted for each country, considering 1994 as base year, to assess the progress of energy security until 2015 in the countries. Additionally, South America's security performance is compared to the top ten countries ranked by the *Energy Trilemma Index* (i.e.: Denmark, Finland, Germany, France, Norway, Netherlands, New Zealand, Austria, Switzerland and Sweden).

In the last chapters, conclusions and suggestions for future works are provided. Future works are suggested to provide a more detailed analysis for each country and for the region, in order to help the development of energy policies that may improve the countries' and region's performance.

1. Energy security assessment

1.1. Energy security conceptualization

According to Wolfers (1952, p. 485) “security, in an objective sense, measures the absence of threats to acquired values and, in a subjective sense, the absence of fear that such values will be attacked”. Silva H. I. (2015, p. 18) mentioned that security is a slippery term as it is “settled in the human feelings, which can assume different forms and emphases, varying according to material goods, institutional commitments and vulnerabilities to which they are exposed”. Thus, it is difficult to establish an absolute definition of security as it is an inherently relational concept, depending of the individual risk, or threat, perception (Freedman, 1992).

After the Cold War, several security concepts emerged according to ideologies applied, such as National Security, Common Security, Collective Security, Shared Security, Human Security, Cooperative Security, and Sustainable Security. Before the Cold War, the concept of security was restricted to threats related to military character. With the creation of United Nations, non-military aspects were included in security agenda.

Spanish Institute of Strategic Studies (2011) distinguished two trends in the security’s concept. The first trend assumes that “the State is the essential object of security” (Spanish Institute of Strategic Studies, 2011, p. 3). With globalization and the problems raised by it, which are cross-border, a generic idea introduces a second trend “in which individuals and/or social groups are the center of attention”, also named as *Human Security*, including dimensions as economy, food, sanity, politics, environment and people individual protection. A new trend then rises as a multidisciplinary approach for security, called Sustainable Security, which can be mean as a balance among critical, ecologist and pacifist orientation (Oxford Research Group, 2017).

The different dimensions considered in the conceptualization of security permit the inclusion of energy issues in security policies. Silva H. I. (2015) mentioned that three logics can be identified to explain the relationship between security and energy in different contexts: (1) the logic of war, (2) the logic of subsistence, and (3) the logic of “total” energy security. The coexistence of these three logics will be determined by the hierarchy established for each one, influencing the definition of concepts, standards and political instruments.

Energy security has emerged as a policy concern in the early 20th century connected to oil supply for armies. The first academic discussions on energy security date from the 1960s and 1970s, with the oil crises occurred in this period. The concern on energy situation entered as the main topic of global agenda in 1973, when the six Persian Gulf members of OPEC decided to raise the posted price by 70%. With the oil price stabilization and the receding threat of political embargo in the 1980s and 1990s, the research in energy security has declined. In the 2000s, with the crescent demand in Asia, disruption of gas supply in Europe, and environmental and sustainability concerns on green house gas emission, pressuring the de-carbonization of energy systems, energy security has became a recurring matter in energy studies (Cherp & Jewell, 2014) [*Fig 1*].

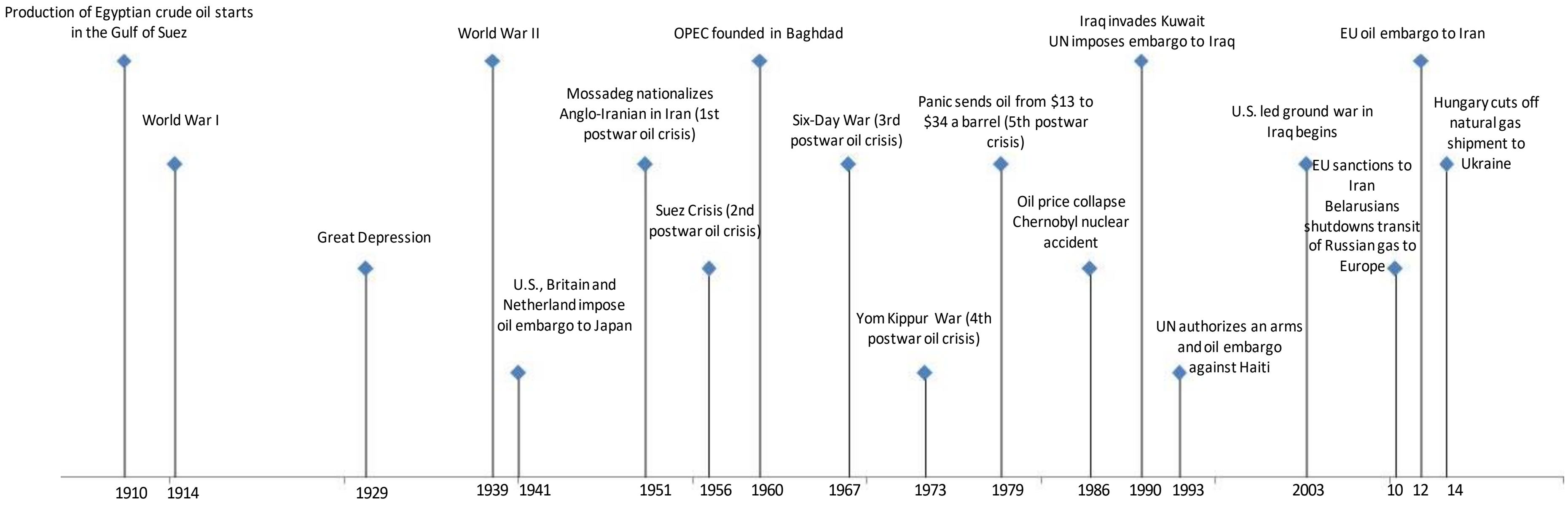

Fig 1: Timeline of Oil History. Source: Adapted from (Yergin, 1991)

Despite the discussions, the term energy security has not been clearly defined yet. A multitude of concepts has been applied to specify the assumptions that shall be taken in the measuring of the energy security of a country or region. Winzer (2012) reviewed a large quantity of energy security concepts discussed by several authors and categorized them into three groups, according to the source of the risk, the scope of the impacts, and the severity filters (speed, size, sustention, spread, singularity and sureness of impacts) [*Fig 2*].

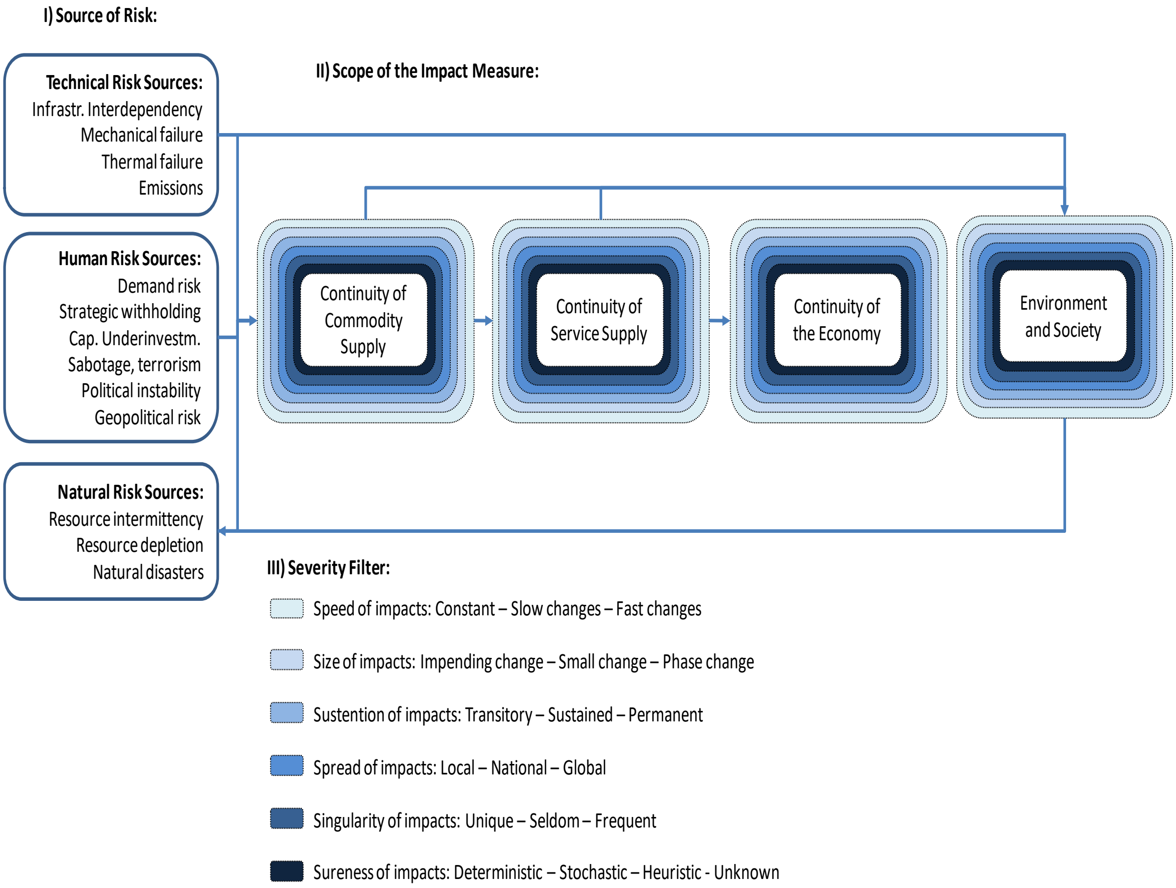

Fig 2: Dimensions of energy security. Source: (Winzer, 2012)

The first group is related to those authors who focus on the concept of commodity supply continuity, named "reliability", which considers the system's ability to provide adequate energy for consumers (system adequacy), and the ability of the system to withstand disturbances (system security). Department of Energy and Climate Change (2009, p. 19) defined that "energy secure means that the risks of interruption to energy supply are low". According to Winzer (2012), other examples of this group of authors are:

Lieb-Dóczy, Börner, and MacKerron 2003; Wright 2005; Scheepers et al. 2007; Ölz, Sims, and Kirchner 2007; Hoogeveen and Perlot 2007.

The second group introduces additional subjective severity filters and is more related to the price variations resulted from energy scarcity. International Energy Agency (2011) conceptualizes energy security in terms of the physical availability of supplies to satisfy demand at a given price. Winzer (2012) mentioned that similar definitions have been used in Yergins 1988; Luciani 2004; Vicini et al. 2005; Andrews 2005; Fondazione Eni Enrico Mattei (FEEM) 2008; Jun, Kim, and Chang 2008; Le Coq and Paltseva 2009. Mabro (2008, p. 3) also exemplified subjective severity filters defining that "security is impaired when supplies are reduced or interrupted in some places to an extent that causes a sudden, significant and sustained increase in prevailing prices".

The last group encompasses the authors who extend the scope of the impact measured to the price and continuity of services, to the economy and to sustainability and safety issues, described by the concepts of affordability and acceptability. The Asia Pacific Energy Research Centre proposed that energy security is the "ability of an economy to guarantee the availability of energy resource supply in a sustainable and timely manner with the energy price being at a level that will not adversely affect the economic performance of the economy" (Intharak et. al., 2007). Similar understandings are proposed in European Commission 2000; Verrastro and Ladislaw 2007; Kruyt et al. 2009 (Winzer, 2012).

Based on all these assumptions and dimensions applied to energy security conceptualization, it is expected that overlapping between measures to promote energy security may occur. In these terms, Winzer (2012) suggested that energy security should be then conceptualized as energy supply continuity to reduce the risk of overlapping between policy objectives of energy security, energy efficiency and sustainability.

The European Commission established that the central target of EU energy policy is to provide all Europeans with secure, sustainable, and competitive energy. The three pillars of the Europe Union's energy policy are efficiency, sustainability and security of energy supply. Similar to Winzer's categorization of risk, the Green Paper *Towards a European Strategy for the Security of Energy Supply* (European Comission, 2001) classifies the hazards for energy supply in four dimensions of risks: physical risks, economic risks, social risks, and environmental risks.

Physical risks are related to the disruption of energy supply due to exhaustion of energy sources or stoppage of production, in permanent terms; and due to strike, geopolitical crisis or natural disasters, in temporary terms. Economic disruptions are caused by erratic fluctuations in the price of energy products. Social risks are caused by the instability of energy supplies, which is likely to lead to social demands, and even to social conflicts. Energy chain can also cause environmental damages, whether occurred accidentally or as a result of polluting emissions (European Comission, 2001)

When sustainability is considered, Sustainable Energy Security (SES) rises as a new concept, defined as "provisioning of uninterrupted energy services in an affordable, equitable, efficient, and environmentally benign manner" (Narula & Reddy, 2015, p. 149), which can include sustainability in harvesting/extraction of energy resources, transformation of primary energy to electricity, transportation, distribution and final supply of energy.

Sousa (2011) mentioned that energy security is a multidimensional concept, considering quantitative and qualitative characteristics. The quantitative aspects are related to energy supply and its "correlated consistency and long-term resilience, including cost control across supply chain". Externalities are parameters to measure the qualitative performance of energy security and can be exemplified by the greenhouse gas emissions and other environmental impacts or health issues from energy generation and consumption

The determination of the energy security of a country or region is important to define the current position and to guide the development of energy policies. As a result of the vastness of concepts, many methodologies for measuring the energy security were developed and can be applied according to the concept defined and applicability to peculiarities and approach of the region studied (Radovanovic, Filipovic, & Pavlovic, 2017). However, it is impossible to compare the energy security indexes resulting from different methodologies, as "there is a gap in the systematic assessment of these indexes, such as their specific focus and the manner which they are constructed" (Ang, Chong, & Ng, 2015, p. 1078). The result of the energy security assessment is influenced by the selection of the conceptual boundaries dimensions. As Winzer (2012, p. 41) mentioned, "the common concept behind all energy security definitions is the absence of, protection from or adaptability to threats that are caused by or have an impact on energy supply chain".

Most of the existing methodologies quantify energy security considering the supply-oriented concepts mentioned above, and do not consider sustainability indicators as parameters for energy security evaluation. Sovacool et. al. (2011, p. 5846) commented that many studies on energy security "rely on incomplete or inconsistent definitions of energy security, centered on technical and economic aspects such as security of fossil fuel supply or end-user prices."

Whereas all the above, and to attend the sustainability approach suggested by this project, this study considered the concept of energy security which includes the economic, social and environmental issues related to the energy chain. Bhaskar (2013) definition of energy security was selected: "the continuous availability of energy in varied forms, in varied quantities, and at reasonable prices without causing hindrance to other securities like social security, food security, and national security of countries and without detrimental effects on the environment." Based on this concept, the existing assessment methodologies were evaluated to verify their consistence to the present proposal to then, be applied in the evaluation of South American energy security.

1.2. Energy security assessment methodologies

A wide range of methodologies were developed over the time, considering different dimensions and metrics, according to the energy security concept adopted. Chong, Ang, & Ng (2015) identified over 40 studies proposing different indexes to measure energy security. However, to the best of our knowledge, there isn't yet a study applied specifically to South American countries, a circumstance that give us the opportunity to contribute with an analysis of the energy security in this region. In this section, the main available methodologies will be discussed.

In 2011, the International Energy Agency developed the Model of Short-term Energy Security (MOSES). The model permits to combine and to interpret indicators related to supply aspects of energy security, based on quantitative indicators that measure two aspects of short-term energy security (days or weeks): risks of energy supply disruption, and resilience, or the "ability of a national energy system to cope with such disruptions" (International Energy Agency, 2011, p. 2). The model evaluates and compares the energy security of IEA countries, defining their energy security profiles and grouping them based on similar combination of risks and resilience factors. It does not rank countries from most to least secure. It addresses four dimensions of energy security, considering external and domestic factors, for primary energy sources and secondary fuels [*Table 1*].

Table 1: Dimensions of energy security addressed by MOSES

	Risk	**Resilience**
External	Risks associated with potential disruption of energy imports	Ability to respond to disruptions of energy imports by substituting with other suppliers and supply routes
Domestic	Risks arising in connection with domestic production and transformation of energy	Domestic ability to respond to disruptions in energy supply such as fuel stocks

Source: (International Energy Agency, 2011)

The Institute for 21st Century Energy of U.S. developed two energy security indexes: the International Index of Security Energy Risk, Brazil being the only South American country considered in the last report, and the Index of U.S. Energy Security Risk. The first one quantifies the energy security of 25 countries, and analyzes eight metric categories: global fuels, fuel imports, energy expenditures, price and market volatility, energy use intensity, electric power sector, transportation sector, and environmental [*Table 2*]. The second one applies quantifiable data, historical trend information, and government projections to identify the policies and other factors that contribute positively or negatively to U.S. energy security.

Table 2: Index Structure – International Index of Energy Security Risk

Metric by classification	Definition
Global Fuel Metrics	
Security of world oil reserves	Global proved oil reserves weighted by each country's relative Freedom Index and by an index of global diversity of oil reserves.
Security of World Oil Production	Global oil production weighted by each country's relative Freedom Index and by an index of global diversity of oil production.
Security of World Natural Gas Reserves	Global proved natural gas reserves weighted by each country's relative Freedom Index and by an index of global diversity of gas reserves.
Security of World Natural Gas Production	Global natural gas production weighted by each country's Freedom Index and by global diversity of gas production.
Security of World Coal Reserves	Global proved coal reserves weighted by each country's relative Freedom Index and by an index of global diversity of coal reserves.
Security of World Coal Production	Global coal production weighted by each country's relative Freedom Index and by an index of global diversity of coal production.
Fuel Import Metrics	
Petroleum Import Exposure	Net petroleum imports as a percentage of total national petroleum supply, adjusted to reflect the reliability of international petroleum production (measured using the Freedom Index) and the diversity across producing countries.
Natural Gas Import Exposure	Net natural gas imports as a percentage of total national gas supply, adjusted to reflect the reliability of international gas production (measured using the Freedom Index) and the diversity across producing countries.
Coal Import Exposure	Net coal imports as a percentage of total national coal supply, adjusted to reflect the reliability of international coal production (measured using the Freedom Index) and the diversity across producing countries.
Total Energy Import Exposure	Net energy imports as a share of total primary energy consumption.
Fossil Fuel Import Expenditures per GDP	Net fossil fuel import costs as a share of GDP.
Energy Expenditure Metrics	
Energy Expenditure Intensity	Total real cost of energy consumed per real $1,000 USD of GDP per year.
Energy Expenditures per Capita	Total real dollar cost of the energy consumed per person per year.
Retail Electricity Prices	Average electricity costs in real cents per kWh.
Crude Oil Prices	Real cost per barrel of crude oil.
Price & Market Volatility Metrics	

Metric by classification	Definition
Crude Oil Price Volatility	Annual change in crude oil prices, averaged over a three-year period.
Energy Expenditure Volatility	Average annual change in energy expenditures per $1,000 USD of GDP.
World Oil Refinery Utilization	Average percent utilization of global petroleum refinery capacity.
GDP per Capita	Total real dollar GDP per person per year.
Energy Use Intensity Metrics	
Energy Consumption per Capita	Million British thermal units (Btu) consumed per person per year.
Energy Intensity	Million Btu of primary energy used in the domestic economy per $1,000 USD of real GDP.
Petroleum Intensity	Million Btu of petroleum consumed per $1,000 USD of real GDP.
Electric Power Sector Metrics	
Electricity Diversity	Average of market share concentration indexes (HHI) of: (1) the primary categories of electric power generating capacity, adjusted for availability; and (2) primary categories of electric power generation.
Non-CO_2 Emitting Share of Electricity Generation	Percentage of total electric power generation contributed by renewables, hydroelectric, nuclear and fossil-fired plants operating with carbon capture and storage technology.
Transportation Sector Metrics	
Transportation Energy per capita	Million Btu consumed in the transportation sector per person per year.
Transportation Energy Intensity	Million Btu of primary energy used in the transportation sector per $1,000 USD of real GDP.
Environmental Metrics	
CO_2 Emissions Trend	Annual change in total national energy related CO_2 emissions.
Energy-Related Carbon Dioxide Emissions per Capita	Metric tons of CO_2 emissions (energy related), per capita.
Energy-Related Carbon Dioxide Emissions Intensity	Metric tons of CO_2 per $1,000 USD of real GDP.

Source: (Institute of 21st Century Energy, 2016).

The Energy Architecture Performance Index developed by the World Economic Forum, measures the energy system performance of 128 countries by applying 18 indicators defined across the sides of what it calls "energy triangle": economic growth and development, environmental sustainability, and energy access and security. Economic growth and development measures the extent to which a country's energy architecture adds or detracts from economic growth. The environmental sustainability sub-index measures the environmental impact of energy supply and consumption. Finally, energy access and security evaluates the extent to which an energy supply is secure, accessible and diversified [*Table 3*].

Table 3: Energy Architecture Performance Index dimensions and indicators

Dimension	Category	Indicator
Economic growth and development	Affordability	Electricity prices for industry
		Diesel – level of price distortion through subsidy or tax
		Super gasoline – level of price distortion through subsidy or tax
	Supports/detracts from growth	Fuel exports (% GDP)
		Fuel imports (% GDP)
	Intensity	GDP produced per unit of energy use
Environmental sustainability	Emissions impact	Average fuel economy for passenger cars
		PM2.5 emissions
		CH_4 emissions from energy sector/total population
		N_2O emissions from energy sector/total population
		CO_2 emissions from electricity production
	Ratio of low-carbon fuel sources in the energy mix	Alternative and nuclear energy
Energy access and security	Self-sufficiency	Diversification of import counterparts
		Energy imports (% of energy use)
	Diversity of supply	Diversity of total primary energy supply
	Level and quality of access	Electrification rate
		Quality of electricity supply
		Population using solid fuels for cooking

Source: (World Economic Forum, 2016).

In 2010, the World Energy Council launched the Energy Trilemma Index, a tool similar to the WEF's and that ranks 125 countries' energy systems, providing an assessment of a country's ability to balance the trade-offs between the three trilemma dimensions: energy security, energy equity, and environmental sustainability (World Energy Council, 2016). Each dimension is split into categories, which are then composed by, in total, 35 indicators [*Table 4*]. It is the method chosen to be applied in this study, as it also captures the context of the energy performance analyzed, in addition to economic and environmental issues (World Energy Council, 2016). The last report applied the index to the Latin America and Caribbean Countries (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Nicaragua, Panama, Paraguay, Peru, Trinidad & Tobago, Uruguay, and Venezuela) and identified that region must work on improving and maintaining its energy security by increasing the energy system's resilience to extreme weather events and improving energy equity. Also, it concluded that the region must diversify the energy supply with low-carbon sources such as solar and wind, and must increase the regional interconnection.

Table 4: Index Structure and Weighting – Energy Trilemma Index

Dimension	Indicator category	Indicator
Energy security	Security of supply and energy delivery	Diversity of primary energy supply
		Energy consumption in relation to GDP growth
		Import dependence
	Resilience	Diversity of electricity generation
		Energy storage
		Preparedness (human factor)
Energy equity	Access	Access to electricity
		Access to clean cooking
	Quality of supply	Quality of electricity supply
		Quality of supply in urban vs. rural areas
	Affordability and competitiveness	Gasoline and diesel prices
		Electricity prices
		Natural gas prices
Environmental sustainability	Energy resource productivity	Final energy intensity
		Efficiency of power generation and T&D
	GHG emissions	GHG emission trend
		Change in forest area
	CO_2 emissions	CO_2 intensity
		CO_2 emission per capita
		CO_2 from electricity generation
Country context	Coherent and predictable policy framework	Macroeconomic environment
		Effectiveness of government
		Political stability
		Perception of corruption
	Stable regulatory environment	Transparency of policy making
		Rule of Law
		Regulatory quality
	Initiatives that enable RD&D and innovation	Intellectual property protection
		FDI & technology transfer
		Capacity for innovation

Dimension	Indicator category	Indicator
	Investability	Number of patents issued by residents Foreign direct investment net inflows Ease of doing business
	Air pollution, land and water impact	Wastewater treatment Air pollution

Source: (World Energy Council, 2016).

The main international energy security indexes and respective dimensions can be observed in *Table 5*.

Table 5: Energy Security Indexes

Source	Name of indicator/Index	Energy security dimensions/issues concerned	No. of indicators
International Energy Agency (IEA)	Model of Short-time Energy Security – MOSES	Crude oil; oil products; natural gas; coal; biomass and waste; bio fuel; hydropower; nuclear power	35
Institute for 21st Century Energy	International Energy Security Risk Index	Global fuels; fuel imports; energy expenditure; price and market volatility; energy use intensity; electric power sector; transportation sector; environmental	28
Institute for 21st Century Energy	Index of U.S Energy Security Risk	Geopolitical; economic; reliability; environmental	37
World Economic Forum (WEF)	Energy Architecture Performance Index	Economic growth and development; environmental sustainability; access and security of supply	18
World Energy Council (WEC)	World Energy Trilemma	Energy security; social equity; environment impact mitigation; political strength; societal strength; economic strength	25

Source: Adapted from (Chong, Ang, & Ng, 2015).

Due to the different approaches and concepts, as already mentioned, it is not recommended to compare methodologies. When doing that, the countries' ranking can present different scores. As example, *Table 6* presents the top ten countries in energy security for three different methodologies.

Table 6: Comparison between rankings of different indexes

Rank	International Energy Security Risk Index	Energy Trilemma Index	Energy Architecture Performance Index
1º	Norway	Denmark	Switzerland
2º	Mexico	Switzerland	Norway
3º	New Zealand	Sweden	Sweden
4º	United States	Netherlands	France
5º	Denmark	Germany	Denmark
6º	United Kingdom	France	Austria
7º	Canada	Norway	Spain
8º	Australia	Finland	Colombia
9º	Germany	New Zealand	New Zealand
10º	France	Austria	Uruguay

Sources: (Institute of 21st Century Energy, 2016), (World Economic Forum, 2016), (World Energy Council, 2016).

Based on this information, Sovacool B. K. (2012) defended four interconnected reasons to the development of energy security index. The first reason concerns the possibility to define energy security as a multidimensional concept by not neglecting equity, environmental quality, social stewardship, governance, regulation and energy efficiency in the analysis of the energy security of a country or region. The second stands for a systematic method, which considers comparative indicators, "can inform energy policy and build institutional capacity". Also, a multidimensional index allows the analysis of the energy security performance over the years, permitting the evaluation of factors with higher influence on scores and the identification of dimensions that improve or worsen. Finally, the fourth and last reason for creating an energy security index that does not focus only in energy supply, is that it enables the identification of trade-offs within the different dimensions and the improvement opportunities in each one. These reasons guided the selection of the methodology to be applied in this research.

1.3. Energy security assessment in South America

South America has its vast availability of energy resources may play an important role on global energy security. The measured oil reserves in South America represent 19.3% of the world's reserves and are equivalent to 115 years of production in 2015. Venezuela accounts for 91% of the region's reserves. Brazil comes second with 5%. South America's hydroelectric potential of 2,842 TWh, 26.4% of which is in operation, is equivalent to 18% of the world's potential. Brazil has the greatest potential in the region (44% of the total), followed by Peru, with 13.9% (Ministry of Mine and Energy, 2016).

According to the International Energy Agency (2017), the Non-OCED American countries (Central and South America, excluding Chile) are responsible for around 5% of total energy produced in the world (816 Mtoe) and export more than import (-167 Mtoe). Brazil, Venezuela and Colombia are the top three energy generator South American countries with 279.4 Mtoe, 182.7 Mtoe and 124.7 Mtoe, respectively. Brazil, Argentina and Venezuela are the main energy consumer countries – 51.3%, 15%, and 11.2%.

South America presents 29% of energy being generated from renewable resources. In renewable sources, South America has advantages over the world, with a share of 29.6% in the domestic energy supply in 2015 (30.3% in 2011), against the world average of 13.8%. South America is an energy-exporting region. In 2015, the region's net exports were close to 190 Mtoe, showing a surplus of 31% on domestic energy demand (Ministry of Mine and Energy, 2016).

However, besides the self-sufficiency in energy supply and the wide range of potential energy sources, Oliveira (2010) believes that the countries in the region are not yet prepared to provide relevant energy security levels at the internal market, as there is a lack of energy regional integration between the countries with greater relevance on energy generation and supply. Bassani (2016) and Silva L. (2016) also discussed energy security in South America in the context of the integration of transportation and distribution energy systems among the countries.

Studies conducted in South America for energy security are mostly related to the regional energy integration, supply-oriented, an important parameter to be considered on the development of energy security policies, as mentioned by the European Commission as one of the six priority areas for a safer energy system (Commission of the European Communities, 2008).

Energy security indexes were applied to some of the South American countries or to Latin America and the Caribbean as a whole. The Energy Trilemma Index Report 2016 concluded that the region of Latin America and the Caribbean "must work on improving and maintaining its energy security by increasing the energy system's resilience to extreme weather events and improving energy equity" (World Energy Council, 2016, p. 30). Also, the report suggested that the region shall diversify the energy supply, including more low-carbon sources. Aligned to Oliveira (2010), WEC mentioned the regional interconnection as a key to improve energy security. Finally, the report mentioned the necessity of large-scale investments to achieve all the improvements suggested. The critic for this report is that it does not provide a temporal analysis, so it is not possible to identify how and in which dimension the countries improved or worsened across the years.

The Global EAPI Report 2016 ranked Colombia and Uruguay in the top ten countries, but did not give details about the specificities that each country performed in their indicators. It only mentioned that they maintained high performance across the energy triangle and improved in environmental sustainability.

Brazil was the only South American country analyzed by the International Index for Energy Security Risk 2016 Report. It was ranked in 23th position, of 25 countries evaluated. The report provided the historical trend in International Energy Security Risks, from 1980 until 2014. According to it, since 2011, Brazil increased its risks, relative to the OECD average, “especially in metric scores related to energy expenditures and energy expenditure intensity” (Institute of 21st Century Energy, 2016, p. 14). Also according to this report, risks associated to import and transportation are larger. The country slipped 10 places, from number 13 in 2010 to number 23 in 2014.

2. Methodology

2.1. Selection of the index methodology

As mentioned, the decision of which methodology to apply considered the conformity of the index to the sustainable approach proposed in this study. All the 53 studies incorporating specific energy security indicators and indexes, listed by Ang et.al. (2015), were analysed. In their paper, the indexes were classified according to type of study (temporal, spatial, and projection), to the specific focused area (4As, specific energy supply, economic, environmental, social, and others), and to the index construction (normalization, weighting, and aggregation).

The indexes that the focused area did not cover, simultaneously, economic, environmental and social issues were rejected. Thus, only nine methodologies remained. Of these nine, three were from the same authors, being the same indicators applied to different countries, and all indicators proposed were covered by international methodologies applied to a wider range of countries.

Then, one of the indexes was, actually, a study that suggested the indicators that should be analysed; it was not an index methodology itself. Two of the last ones were very specific to Mexico and Malaysia. Hence, all three were also refused.

The last three were: one index developed by a researcher, with too few indicators to the proposed project, and the other two were the EAPI, developed by WEF, and the Energy Trilemma Index, of WEC. Both suit to the scope, however, the Energy Trilemma Index provided a more robust opportunity to analyse the country context, considering political and societal strength. Therefore, Energy Security Trilemma was selected to be the methodology to be adapted and applied in this work.

2.2. Data collection and calculation

The data collection is based on the material available for consultation during the period of 1994-2015, for ten South American countries (Argentina, Bolivia, Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay and Venezuela), according to the Energy Trilemma Index indicators [*Table 7*]. The data sources considered were the same applied by the Energy Trilemma Index. However, this study also considered some regional and national energy databases, when the Trilemma's data source did not provide all information for the entire period.

Table 8 presents the data sources considered for each indicator. Some indicators were available from 2007, thus, a second analysis was conducted considering these indicators, providing a more detailed analysis of the energy security in the region, but in a shorter period (i.e. 2007-2015). This second analysis compares the South American countries' scores versus the Trilemma's top ten countries in 2016 (Denmark, Switzerland, Sweden, Netherlands, Germany, France, Finland, New Zealand, and Austria).

Table 7: Data availability for Energy Trilemma Index

Dimension	Indicator category	Indicator	Availability	Time-period
Energy security	Security of supply and energy delivery	Diversity of primary energy supply	YES	1990-2015
		Energy consumption in relation to GDP growth	YES	1990-2015
		Import dependence	YES	1990-2015
	Resilience	Diversity of electricity generation	YES	1990-2015
		Energy storage	NO	
		Preparedness (human factor)	YES	2007-2015
Energy equity	Access	Access to electricity	YES	1990-2015
		Access to clean cooking	YES	200-2015
	Quality of supply	Quality of electricity supply	YES	2007-2015
		Quality of supply in urban vs. rural areas	NO	
	Affordability and competitiveness	Electricity prices	YES	1990-2015
		Gasoline and diesel prices	NO	
		Natural gas prices	NO	
Environmental sustainability	Energy resource productivity	Final energy intensity	YES	1990-2015
		Efficiency of power generation and T&D	YES	1990-2015
	GHG emissions	GHG emissions trend	YES	1990-2015
		Change in forest area	YES	1990-2015
	CO_2 emissions	CO_2 intensity	YES	1990-2015
		CO_2 emission per capita	YES	1990-2015
		CO_2 from electricity generation	YES	1990-2015
Country context	Coherent and predictable policy framework	Macroeconomic environment	YES	2006-2015
		Effectiveness of government	YES	1996; 1998; 2000; 2002-2015
		Political stability	YES	1996; 1998; 2000; 2002-2015
		Perception of corruption	YES	2012-2015

Dimension	Indicator category	Indicator	Availability	Time-period
	Stable regulatory environment	Transparency of policy making	YES	2007-2015
		Rule of law	YES	1996; 1998; 2000; 2002-2015
		Regulatory quality	YES	1996; 1998; 2000; 2002-2015
	Initiatives that enable RD&D and innovation	Intellectual property protection	YES	2007-2015
		FDI & technology transfer	YES	2007-2015
		Capacity for innovation	YES	2012-2015
		Number of patents issued by resident	YES	1990-2015
	Investability	Foreign direct investment net inflows	YES	1990-2015
		Ease of doing business	NO	
	Air pollution, land and water impact	Wastewater treatment	NO	
		Air pollution	YES	1995; 2000; 2005; 2010-2015

Table 8: Energy data sources

Energy Trilemma Indicator	Energy Trilemma data source	Source used (South America)	Source used (top ten countries)
Diversity of primary energy supply	IEA	OLADE	Eurostat, IEA
Energy consumption in relation to GDP growth	EIA, World Bank	OLADE, World Bank	EIA, World Bank
Import dependence	World Bank, UNCTAD	World Bank	World Bank
Diversity of electricity generation	EIA	OLADE, World Bank, Authority of Supervision and Social Control of Electricity (Bolivia)	IEA, Eurostat
Preparedness (human factor)	WEF	WEF	WEF
Access to electricity	SE4All GTF	OLADE	World Bank
Access to clean cooking	SE4All GTF	World Bank	World Bank
Quality of electricity supply	WEF	WEF	WEF
Quality of supply in urban vs. rural areas	SE4All GTF	NA	NA
Electricity prices	IEA, WEC	OLADE	Eurostat
Gasoline and diesel prices	GIZ, IMF	NA	NA
Natural gas prices	IEA, WEC, EUROSTAT	NA	NA
Final energy intensity	WEC / Enerdata	World Bank	World Bank
Efficiency of power generation and T&D	WEC / Enerdata	OLADE, World Bank	World Bank
GHG emissions trend	WRI / CAIT	OLADE	UNFCCC
Change in forest area	World Bank	World Bank	World Bank
CO_2 intensity	WEC / Enerdata	World Bank	World Bank
CO_2 emission per capita	WEC / Enerdata	OLADE, World Bank	UNFCCC, World Bank
CO_2 from electricity generation	IEA	OLADE	UNFCCC, IEA
Macroeconomic environment	WEF	WEF	WEF
Effectiveness of government	World Bank	World Bank	World Bank
Political stability	World Bank	World Bank	World Bank
Perception of corruption	Transparency International	World Bank	World Bank
Transparency of policy making	WEF	WEF	WEF
Rule of law	World Bank	World Bank	World Bank
Regulatory quality	World Bank	World Bank	World Bank

Energy Trilemma Indicator	Energy Trilemma data source	Source used (South America)	Source used (top ten countries)
Intellectual property protection	WEF	WEF	WEF
FDI & technology transfer	WEF	WEF	WEF
Capacity for innovation	WEF	WEF	WEF
Number of patents issued by resident	World Bank	World Bank	World Bank
Foreign direct investment net inflows	World Bank	World Bank	World Bank
Ease of doing business	World Bank	World Bank	World Bank
Wastewater treatment	Yale Environmental Index	NA	NA
Air pollution	World Bank	NA	NA

The data collection and aggregation, and values calculation followed the process reported by Energy Trilemma Index [*Fig 3*]. Energy Trilemma Index treats missing values by splitting countries into income and geography groups, replacing the blanks with the mean of the income and geography group. However, in the present study, the country series mean was used to replaced the missing values, considering the following criteria: for each country, there must be more than 60% of data for the period and, the data must not be absent for more than 3 consecutive years.

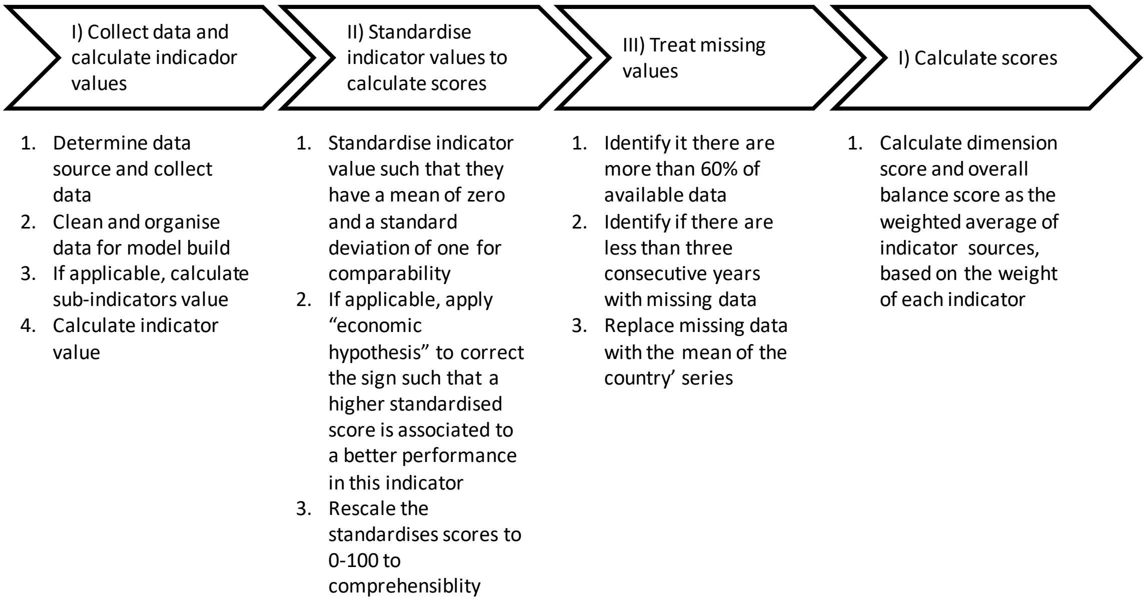

Fig 3: Indicator Aggregation Methodology. Source: Adapted from Energy Trilemma Index.

Energy Trilemma Index defined the Eq. 1 to standardize the indicator scores, for ranking proposes. This standardization approach allows scores to be compared across indicators to ensure cross-indicator, cross-category and cross-dimension comparability.

$$XS_{i,t} = \frac{X_{i,t} - \overline{X}_t}{\sigma_{Xt}} \quad \textbf{(1)}$$

- where $XS_{i,t}$ is the standardized value for each country i, at time t;
- $X_{i,t}$ is the raw score for each country i, at time t;
- $\overline{X}_t$ is the mean of the raw scores for the indicator across all in-scope countries, in time t and,
- σ_{Xt} is the standard deviation of the raw scores for the indicator across all in-scope countries, at time t.

To evaluate the evolution of each country, 1994 was fixed as the base year. Thus, the standardization Eq. 2 for country's analysis was applied:

$$XS_{i,t} = \frac{X_{i,t} - \overline{X}_{1994}}{\sigma_{x_{1994}}} \quad \textbf{(2)}$$

- where $XS_{i,t}$ is the standardized value for each country i, at time t;
- $X_{i,t}$ is the raw score for each country i, at time t;
- $\overline{X}_{1994}$ is the mean of the raw scores for the indicator across all in-scope countries, in 1994 and,
- $\sigma_{x_{1994}}$ is the standard deviation of the raw scores for the indicator across all in-scope countries, in 1994.

The standardized scores may be negative or positive, depending on whether the score is below or above the mean. When there is a negative relationship between the indicator and the performance (i.e. higher values suggest lower performance) the standardized score of some indicators was multiplied by -1. Before indicators be combined into dimensions and country overall scores, standardized scores are rescaled to have a minimum value of 0 and a maximum value of 100, where 0 is the worst performing country and 100 is the best. Energy Trilemma Index defined the Eq. 3 for rescaling, for ranking proposes

$$XSC_{i,t} = \frac{(XS_{i,t} - X_{min,t})*(XSC_{max,t} - XSC_{min,t})}{(X_{max,t} - X_{min,t})} + XSC_{min,t} \quad \textbf{(3)}$$

- where $XSC_{i,t}$ is the scaled score for each country i for standardized indicator score $XS_{i,t}$, at time t;
- $XS_{i,t}$ is the standardizes score for each country i, at time t;
- $X_{min,t}$ is the minimum value of the standardized scores for the indicator across all in-scope countries, in time t;
- $X_{max,t}$ is the maximum value of the standardized scores for the indicator across all in-scope countries, in time t;
- $XSC_{min,t}$ is the post-scaling minimum value of the standardized scores for the indicator across all in-scope countries (i.e. 0) and,

- $XSC_{max,t}$ is the post-scaling maximum value of the standardized scores for the indicator across all in-scope countries (i.e. 100).

For country's specific analysis, scores were rescaled between 0 and 1, and also based in 1994 as fixed year. These were computed by Eq. 4:

$$XSC_{i,t}=\frac{(XS_{i,t}-X_{min,1994})*(XSC_{max}-XSC_{min})}{(X_{max,1994}-X_{min1994})}+XSC_{min} \quad \textbf{(4)}$$

- where $XSC_{i,t}$ is the scaled score for each country i for standardized indicator score $XS_{i,t}$, at time t;
- $XS_{i,t}$ is the standardizes score for each country i, at time t;
- $X_{min,1994}$ is the minimum value of the standardized scores for the indicator across all in-scope countries, in 1994;
- $X_{max,t}$ is the maximum value of the standardized scores for the indicator across all in-scope countries, in 1994;
- $XSC_{min,t}$ is the post-scaling minimum value of the standardized scores for the indicator across all in-scope countries (i.e. 0) and,
- $XSC_{max,t}$ is the post-scaling maximum value of the standardized scores for the indicator across all in-scope countries (i.e. 1).

The comparison with the top ten countries ranked by Energy Trilemma 2016, applied the same methodology used for ranking South American countries. The indicator's values for the region were calculated by the mean of South American countries' indicators.

Due to data availability, and before applying the standardization and rescaling equations, this study made modifications to some indicators or sub-indicators, either in the data concept or in the calculation equation. Still, it maintained the purpose of what to be measure. The details about the modifications and other assumptions are described below.

Diversity of primary energy supply

Trilemma suggests to calculate the Herfindahl-Hirschmann Index (HHI) and to distribute the weights among the remaining indicators of the category if the country's energy reserves equals or exceed established threshold levels. Because there is no available data of country's energy reserves, this study only applied the HHI to calculate the scores.

Access to electricity, GHG emissions trend and Change in forest area

These indicators are calculated by comparing to a base year. The rate of improvement in access to electricity is calculated for a period of ten years back, while the trend in GHG emissions is measured for 12 years, and the change in forest area for five years back. Trilemma applies the Eq. 5, Eq. 6 and Eq. 7 for these indicators.

$$\text{Rate of improvement in access to electricity}=\left(\frac{\text{access to electricity in 2010}}{\text{access to electricity in 2000}}\right)^{\frac{1}{9}}-1 \quad \textbf{(5)}$$

$$\text{GHG emissions trend}=\left(\frac{\text{CO2 emissions from energy sector in 2012}}{\text{CO2 emissions from energy sector in 2000}}\right)^{\frac{1}{11}}-1 \quad \textbf{(6)}$$

$$\text{Change in forest area}=\left(\frac{\text{forest area in sq.km in 2015}}{\text{forest area in sq.km in 2000}}\right)^{\frac{1}{4}}-1 \quad \textbf{(7)}$$

As this study analyses the energy security in a time series, it calculated these indicators on an annual basis with Eq. 8.

$$X=\frac{a_{(t)}}{a_{(t-1)}}-1 \quad \textbf{(8)}$$

- where X is the indicator to be calculated and,
- a is access to electricity/CO_2 emissions/forest area

Electricity prices

Electricity prices are measured by the mean of electricity prices for households and industries. Energy Trilemma determines that electricity prices for households must be calculated by Eq. 9.

$$\text{Electricity prices for households}=\left(\frac{\text{average household consumption*electricity prices for households}}{\text{GDP per capita (PPP)in international USD}}\right) \quad \textbf{(9)}$$

As there is not enough data about the average household consumptions, this study considered only the electricity prices for households (US$/KWh). Electricity prices in Europe, both for households and industry, are measured in EU$/KWh. Thus, the author converted the prices for the top 10 countries considering the USD currency in 2011. Finally, the Eq. 10 computes the electricity price indicator:

$$\text{Electricity price}=(0.5*\text{electricity price for household})+(0.5*\text{electricity price for industry}) \quad \textbf{(10)}$$

Final energy intensity, CO_2 emissions per capita and CO_2 from electricity generation

Energy Trilemma defines caps for these three indicators. For final energy intensity indicator the cap is 0.15 koe/US$. However, for this study, the data found for all countries within the scope is available in MJ/$2011 PPP GDP. For CO_2 emission per capita, Energy Trilemma established the cap of 20.0 CO_2 intensity per capita (i.e. kCO_2/GDP/capita); this research considered the total amount of CO_2 emitted from energy sector per capita ($GgCO_2$/capita). Finally, 5000 gCO_2/kWh is the cap defined for the CO_2 emitted from electricity generation; however, this study applied the unit as $GgCO_2$/GWh. Considering these changes, this study applied no cap, neither for these indicators nor in the entire research.

Efficiency of power generation and T&D

This indicator is calculated by the Energy Trilemma, with the help of Eq. 11; as the mean of efficiency of power generation and the rate of electricity T&D losses.

$$\text{Efficiency of power generation and T\&D} = \frac{\text{efficiency of power generation} + \text{rate of electricity T\&D losses}}{2} \quad \textbf{(11)}$$

However, this study applied only the percentage of electricity T&D losses provided by the World Bank data.

Energy Trilemma assigns weights equally distributed for the dimensions, indicator categories and indicators. As this study did not calculate all indicators, it defined a new weight distribution, maintaining the assumption of equal division among the parameters [*Table 9*].

Table 9: Applied weight distribution

Dimension	%	Indicator category	% (Energy Trilemma)	% (1994-2015)	% (2007-2015)	Indicator	% (Energy Trilemma)	% (1994-2015)	% (2007-2015)
Energy security	30	Security of supply	15	15	15	Diversity of primary energy supply	5.0	5.0	5.0
						Energy consumption in relation to GDP growth	5.0	5.0	5.0
						Import dependence	5.0	5.0	5.0
		Resilience	15	15	15	Diversity of electricity generation	5.0	15.0	7.5
						Energy storage	5.0	0	0.0
						Preparedness (human factor)	5.0	0	7.5
Energy equity	30	Access	10	15	10	Access to electricity	5.0	15.0	5.0
						Access to clean cooking	5.0	0.0	5.0
		Quality of supply	10	0	10	Quality of electricity supply	5.0	0.0	10.0
						Quality of supply in urban vs. rural areas	5.0	0.0	0.0
		Affordability and competitiveness	10	15	10	Electricity prices	3.3	15.0	10.0
						Gasoline and diesel prices	3.3	0.0	0.0
						Natural gas prices	3.3	0.0	0.0
Environmental sustainability	30	Energy resource productivity	10	10	10	Final energy intensity	5.0	5.0	5.0
						Efficiency of power generation and T&D	5.0	5.0	5.0
		GHG emissions	10	10	10	GHG emissions trend	5.0	5.0	5.0
						Change in forest area	5.0	5.0	5.0
		CO_2 emissions	10	10	10	CO_2 intensity	3.3	3.3	3.3
						CO_2 emission per capita	3.3	3.3	3.3
						CO_2 from electricity generation	3.3	3.3	3.3

Dimension	%	Indicator category	% (Energy Trilemma)	% (1994-2015)	% (2007-2015)	Indicator	% (Energy Trilemma)	% (1994-2015)	% (2007-2015)
Country context	10	Coherent and predictable policy framework	2	0	2.5	Macroeconomic environment	0.5	0.0	0.625
						Effectiveness of government	0.5	0.0	0.625
						Political stability	0.5	0.0	0.625
						Perception of corruption	0.5	0.0	0.625
		Stable regulatory environment	2	0	2.5	Transparency of policy making	0.7	0.0	0.83
						Rule of law	0.7	0.0	0.83
						Regulatory quality	0.7	0.0	0.83
		Initiatives that enable RD&D and innovation	2	5	2.5	Intellectual property protection	0.5	0.0	0.83
						FDI & technology transfer	0.5	0.0	0.83
						Capacity for innovation	0.5	0.0	0.0
						Number of patents issued by resident	0.5	5.0	0.83
		Investability	2	5	2.5	Foreign direct investment net inflows	1.0	5.0	2.5
						Ease of doing business	1.0	0.0	0.0
		Air pollution, land and water impact	2	0	0	Wastewater treatment	1.0	0.0	0.0
						Air pollution	1.0	0.0	0.0

3. Results and discussion

3.1. Regional profile – 1994-2015

Energy security in South America increased 19% in the period analyzed. In general, over the years, ESI increased 16% in the region. Energy equity was the dimension with the best rate of improvement – 20%, mainly due to the increase of access to electricity by South American population. Energy security dimension also presented a relevant increase in the period – 19%, as South America behave more as an energy exporter than importer region. Also, the energy mix is more diverse, with the inclusion of renewables sources. A small expansion in environmental sustainability was observed. The dimension rose 9% in the period, drove by the overall improvement in T&D efficiency, and by the reduction trend in CO_2 emissions and deforestation. Country context dimension is higher over the years, as the region received more foreign investments [*Fig 4*].

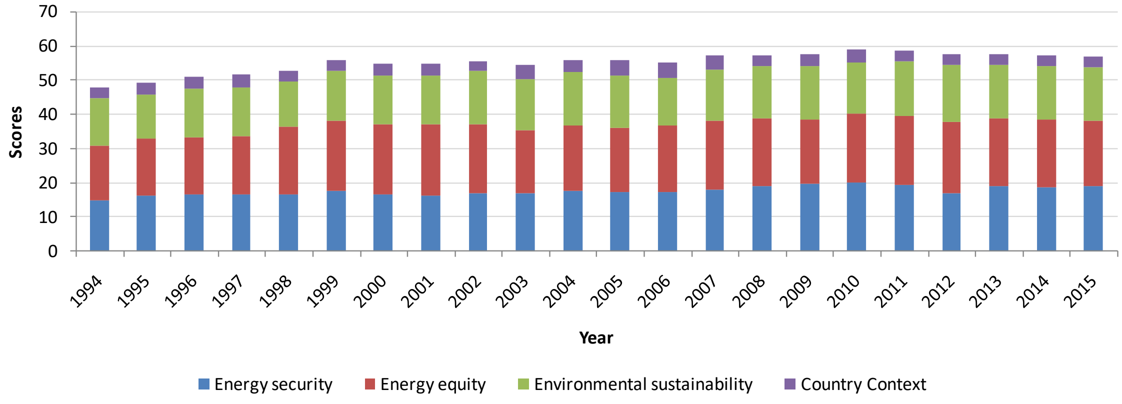

Fig 4: Energy security index and dimensions scores - South America

3.1.1. Energy security dimension

By analyzing the indicators that compose this dimension [*Fig 5*], it seems that the primary energy matrix is becoming less diverse since 2009, with the raise of coal and natural gas. However, when analyzed in detail, the sources classified as "others" increased 75% in relation to 2009, which means that renewable energies have a greater share in the energy matrix. Thus, if these sources were considered separately in the indicator, the final score could be different, i.e. an increase instead of a decrease. South America is an energy export region, and has reinforced this scenario over the period analyzed. Exports increased 10% in the period. The best relation energy import per energy use was observed in 2008.

The top improvement was noticed in the diversity of electricity generation indicator. The electricity matrix became 34% more diverse. Hydro is still the energy source widely used in South America, however, its participation has decreased during the period – 77% in 1994 vs. 54% in 2015. Despite the improvement in the final score, the diversification of the electricity matrix was motivated by the larger increases in the shares of nuclear and oil based thermo power plants, and by the shy growth of renewables. Hence, the mix is more diversified, but less clean, as can be confirmed with the increase on CO_2 emissions to be discussed forward.

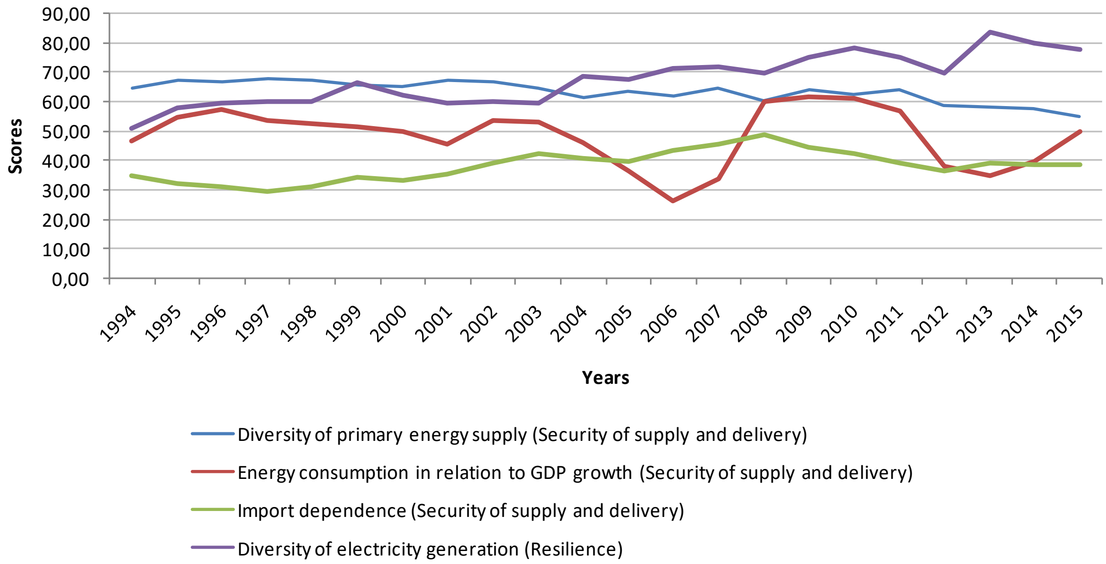

Fig 5: Evolution of energy security dimension's categories by each indicator' scores

3.1.2. Energy equity dimension

Energy equity dimension is composed by two indicators: access to electricity and electricity prices. As observed in *Fig 6*, electricity was distributed to more people. Access to electricity improved 16% in the last years. Electricity prices, both for domestic and industry sectors, presented ups and downs in the period. In general, the indicator improved its score.

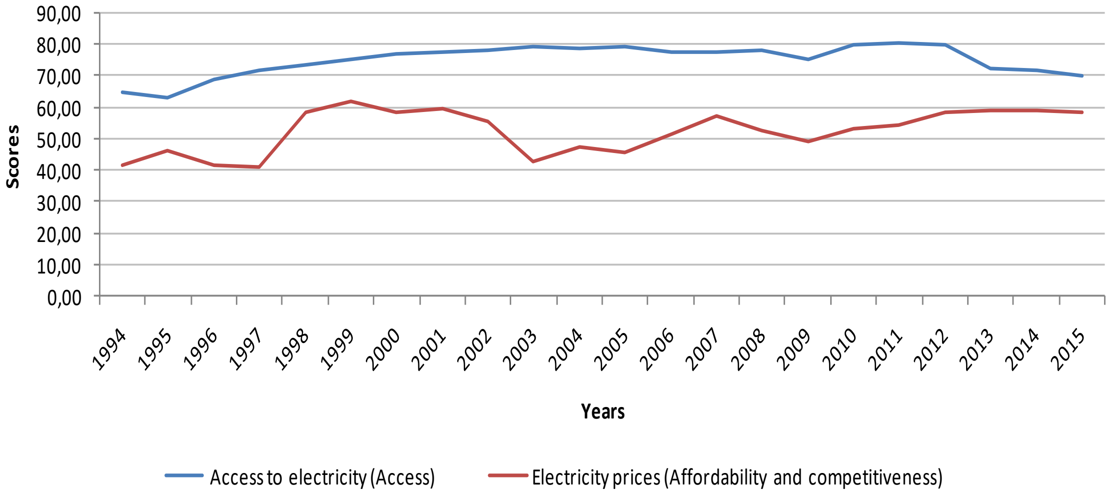

Fig 6: Evolution of energy equity dimension's categories by each indicator' scores

3.1.3. Environmental sustainability dimension

The final energy intensity presented a little decrease in the period – 5%. Between 2002 and 2007, the region lost efficiency in the energy consumption. The retake happened in 2007, with fluctuation until 2015, when the region presented virtually the same level of energy consumption per GDP observed in 1994 [*Fig 7*]. The efficiency of power generation and T&D, measured by the percentage of losses in the output, increased its rates, meaning that the quality of electricity transmission and distribution improved along the years. Data was missing in 2015, so the mean of the series were made to fulfil this gap. As a consequence, an abrupt decline in 2014 is observed.

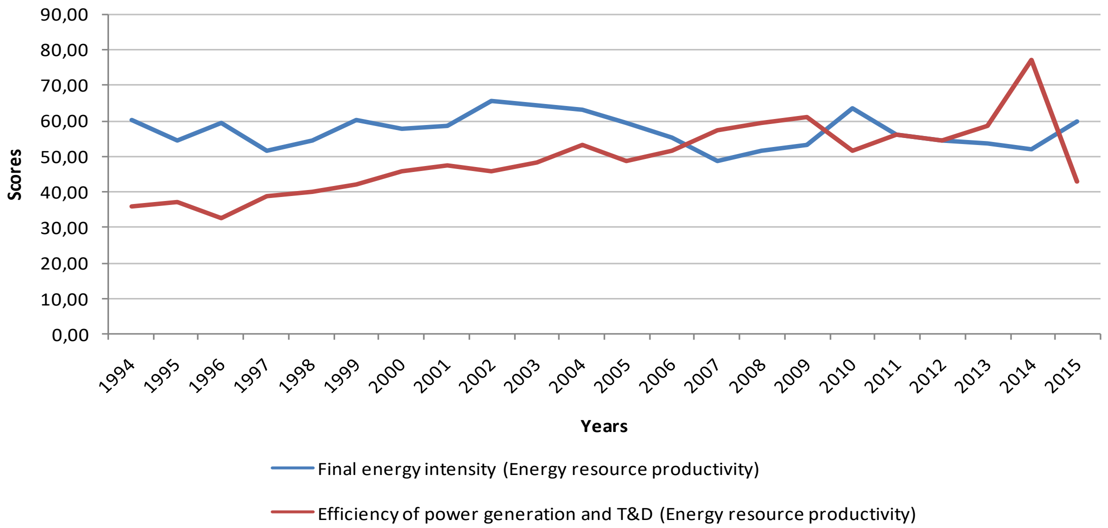

Fig 7: Evolution of energy resource productivity category by each indicator' scores

The forest coverage area, measured in squared meters, reduced along the period. However, the deforestation trend, year by year, declined, improving the final scores for this indicator, as can be seen in **Error! Reference source not found.**. GHG emission trend is increasing and decreasing successively. Yet, the indicator increased its score over the year, meaning that the trend is to reduce GHG emission from the energy sector [*Fig 8*].

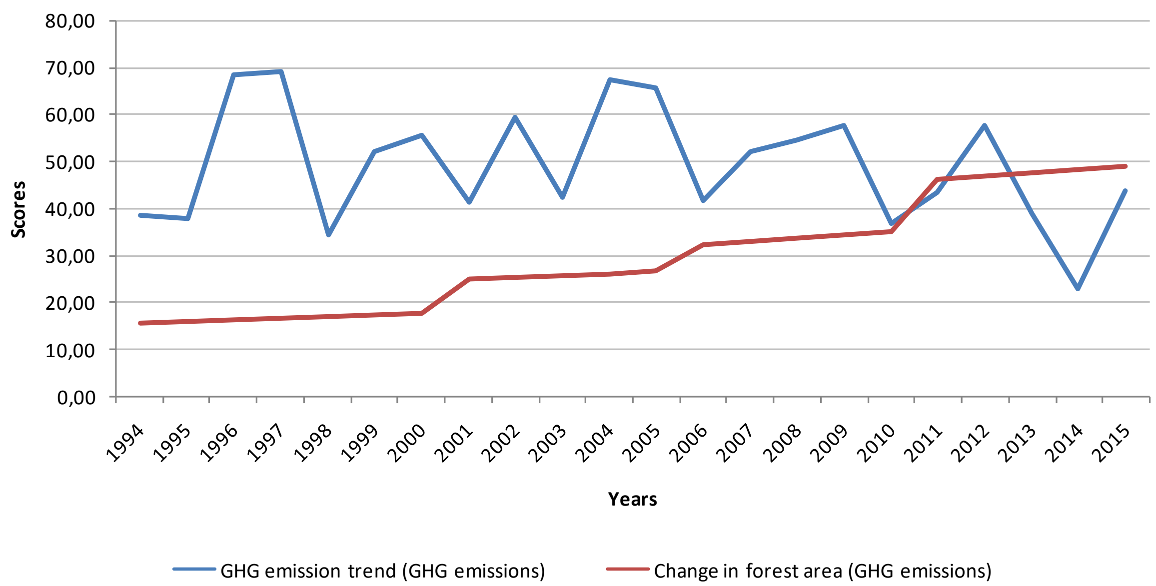

Fig 8: Evolution of GHG emission trend category by indicator' scores

The only environmental sustainability's category that presented a reduction in the score was CO_2 emissions (6%). The CO_2 intensity, measured in kilo of CO_2 emitted by the energy sector per unit of GDP, and the CO_2/KWh indicators show that region's energy matrix is becoming more carbon intense. Also, the quantity of CO_2 emitted per capita is – 22% over the period [*Fig 9*].

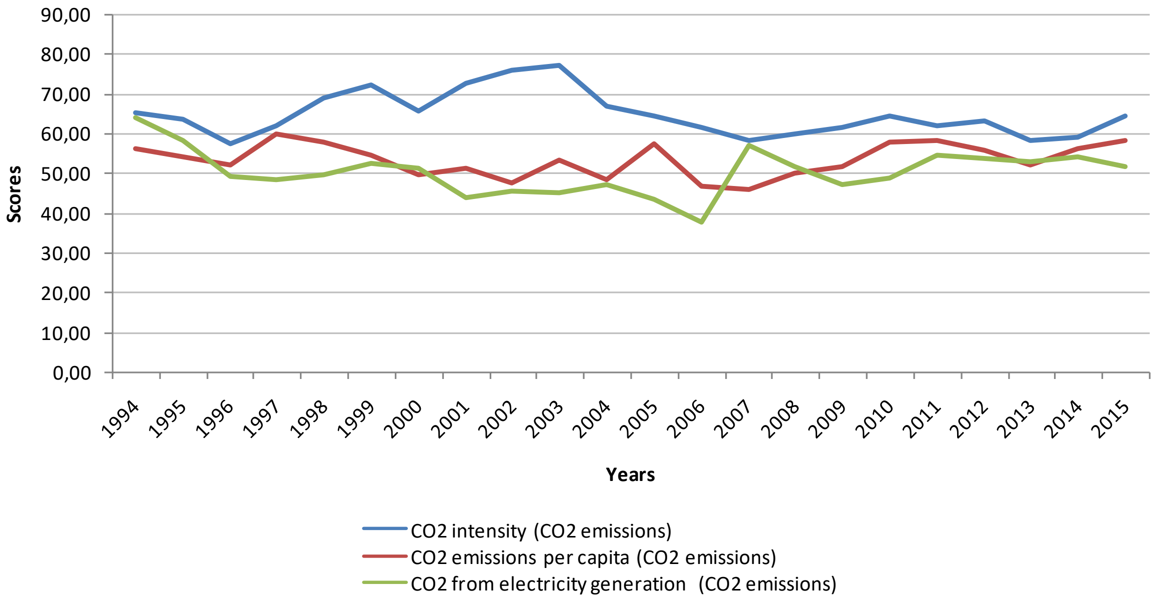

Fig 9: Evolution of CO_2 emissions category by indicator' scores

3.1.4. Country context dimension

South America became less innovative along the years, considering that the number of patents issued per residents decreased 14% in the period analysed. Foreign investment in the region was inconstant, depending on political and economic scenarios that the countries could be facing. As it is known, South America is still an instable region in terms of political framework. However, in general, the region received more funds from foreign investors along the years [*Fig 10*].

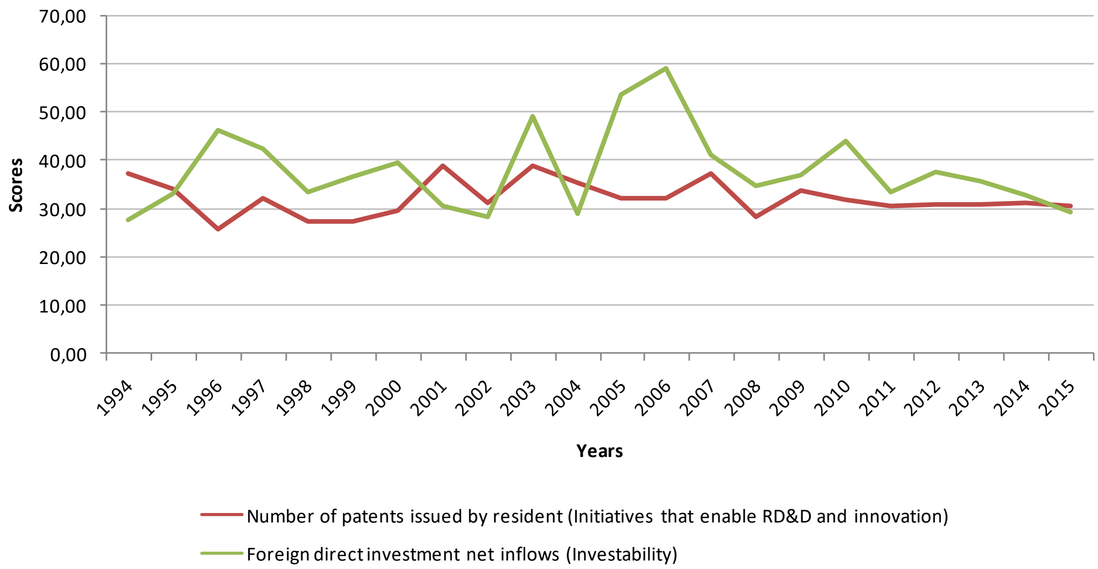

Fig 10: Evolution of country context dimension's categories by indicator' scores

Chile and Argentina alternated the first position of the most energy security countries; in exception to year 1997, when Colombia was the country with the best score [*Fig 11*]. In 1997, Colombia was above the regional mean for all dimensions but country context. In addition, the country was the best one in the energy security dimension due to the good performance in all categories' indicators. Colombia maintained a good performance over the next years, being part of the top five; however, it was not good enough to keep the country in the first position.

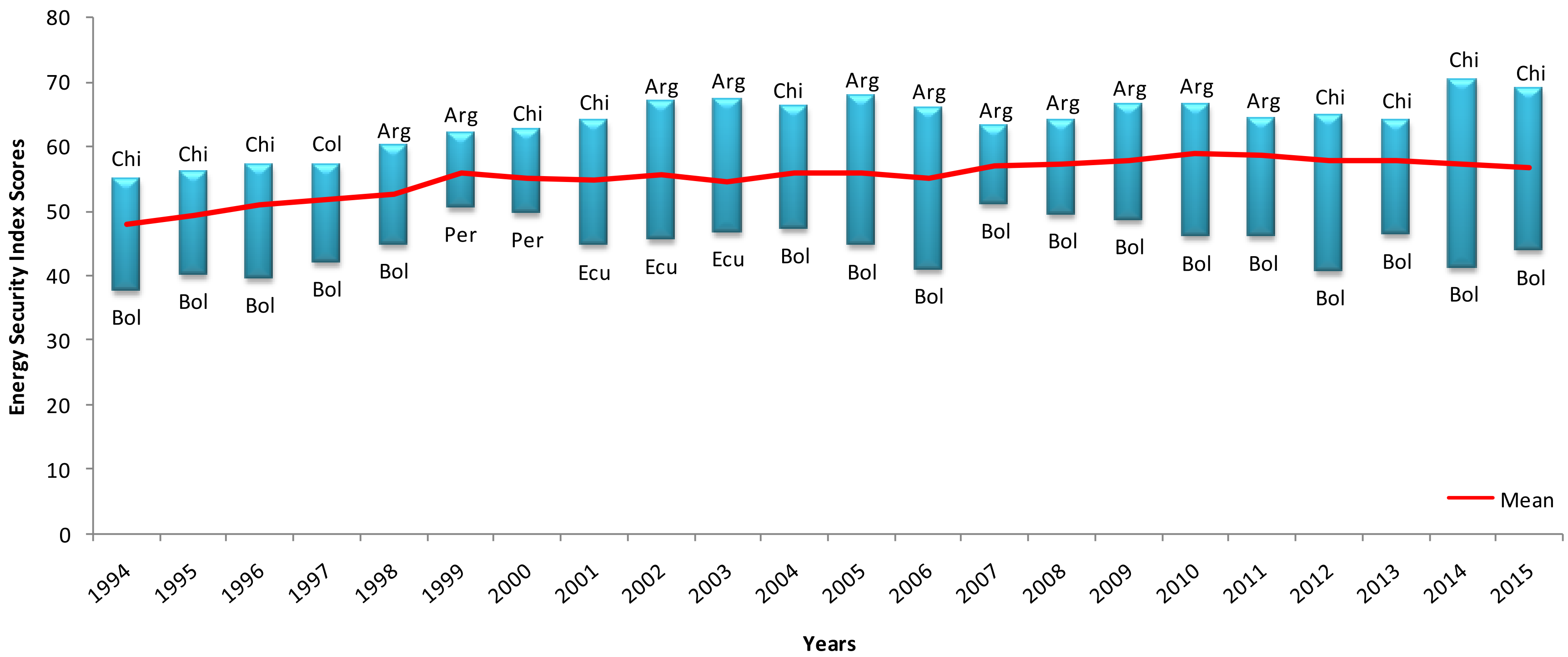

Fig 11: Best and worst energy security performance in South America

	94	95	96	97	98	99	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15
Min	55	56	57	57	60	62	63	64	67	67	66	68	66	63	64	67	67	64	65	64	70	69
Max	38	40	40	42	45	51	50	45	46	47	47	45	41	51	50	49	46	46	41	46	41	44
Mean	48	49	51	52	53	56	55	55	55	55	56	56	55	57	57	58	59	59	58	58	57	57

3.2. Countries' performance

3.2.1. Argentina

In 2015, compared to 1994, the country improved its performance in 7%. From 1994 until 2001, energy security index is virtually the same in the country. In 2002, an improvement is observed, lasting until 2006, when a decrease in the scores started. Since 2006, the Argentine's ESI continuously fell until 2015 [*Fig 12*].

Energy security dimension's performance is almost the same during the entire period. The highest value is observed in 1994, meaning that energy security dimension slightly worsened across the years. The lowest mark is in 2014, when energy import rates reached its maximum, and the diversity of electric matrix was the second worst registered, reflecting the increase of fossil fuel power plant' share. Also, primary energy mix became somewhat less diverse over the years. The performance of energy equity dimension was good enough to compensate the poor score of the energy security dimension in 2014. Energy equity dimension is always improving the performance in relation to 1994, except for the period between 1997 and 1999. In this period, electricity price for households was about 19% higher than 1994. After this period, the prices reduced, both for households and for industries. From 2000 until 2015, the mean of electricity price for households was 42% smaller than 1994; for industry, it was half of the 1994's. The biggest difference from one year to another is observed between 2001 and 2002. In 2001, electricity price for household was 0.11 US$/KWh; in the next year, the price fell down to 0.03 US$/KWh. For industries, it changed from 0.07 US$/KWh to 0.02 US$/KWh. In 2002, the services taxes were frozen to control the inflation that Argentina was facing due to the 2001' Argentinean crises that the previous govern of ex-President Fernando de la Rúa leaved in the country. Until 2015, the Kirchners maintained subsides to electricity services, thus, the prices remained low. The indicator of access to electricity is always improving. In 1994, around 92% of Argentinean population were connected to the grid; in 2015, this rate increased to 99%.

As to energy security dimension, no great changes were observed in environmental sustainability. The worst year for the environment in Argentina was 2004, when the country presented the highest rate for kilo of CO_2 per GDP and one of the worst trend in the CO_2 emission by energy sector. The best year was in 2001 – 30% better than the entire period. The atmospheric emissions categories were the responsible for this performance, presenting one of the lowest values for CO_2 emissions rates.

Argentina always presented one of the best marks for country context dimension. The best score was observed in 1999, when the highest amount of foreign investment was applied in the country. In 2001, this dropped 40% in relation to 1994, being the worst mark reached by the dimension, due to the melting down of country's economy.

In general, since 2006, there is a constant decline in the Argentinean ESI. This reflected the decrease of all dimensions in this period. In 2015, comparing to 2006, energy security dimension was 23% lower; energy equity, 12%; environmental sustainability, 4%; and country context reduced 46%. In this period, the primary energy and electric matrixes reduced their diversity, with the increase of the share of fossil fuels thermo power plants and the consumption of vehicular natural gas. As a consequence of the economic crises started in 2001, vehicles owners, searching for reducing expenses with fuel, made about 30.000 of monthly conversion (Castro & Freitas, 2004). As a result, the CO_2 emitted increased, worsening the environmental sustainability performance. The electricity price for households started to grow in 2006. However, it always remained bellow 2001's levels. The reduction in country context dimension is a reflection of the lower issuing of patents per resident and to the less amount of foreign money invested in the country.

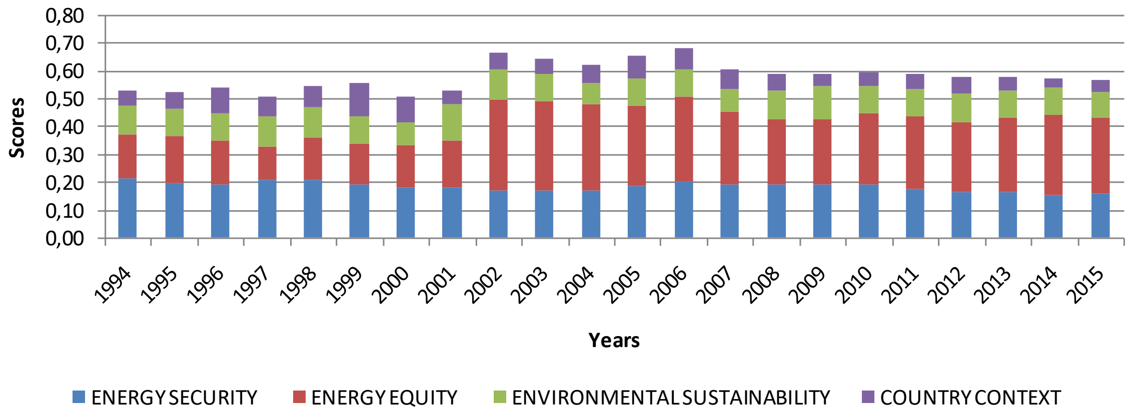

Fig 12: Energy security dimensions scores – Argentina

3.2.2. Bolivia

Comparing 2015' score to 1994's, Bolivia was the country with the highest increase in the energy security index – 20% [*Fig 13*]. Energy equity was the dimension with the greatest expansion – 107%, driven by the huge increase in the rates of electricity access: in 1994, 47% of Bolivian population had access to electricity; in 2015, this number was about 88%. In 2008, Bolivian government officialised the *Electricity to Live with*

Dignity program, which established goals to increase electricity access in the country, mainly in rural area: to connect 53% of rural households until 2010; 70% until 2015; 87% until 2020; and to have 100% of rural area covered by electricity services until 2025 (National Electricity Company, 2016).

Energy security dimension was virtually the same until 2005. The mean for rest of the period was about 11% less than the mean until 2005. 2015 was 15% below 1994's mark. The diversity of energy sources also decreased since 2005. In 2006, govern of President Evo Moralles nationalized the natural gas production. After that, the share of natural gas increased in the primary energy matrix, in prejudice of the other sources. Natural gas and oil responded to 84% of the primary energy sources supplied in 2015. In 1994, this rate was 66%.

The worst performance in environmental sustainability was in 1996, when the country's trend to emit CO_2 was the highest. In addition, the amount of CO_2 emitted from electricity generation was relevant. After that, environment issues improved and worsened successively across the years. Yet, the mean of the period is 12% better than 1994' score. The best mark was obtained in 2007, when the CO_2 intensity was the smallest one, the trend of deforestation reduction was one of the highest, and the efficiency of transmission and distribution systems was one of the best.

Country context achieved its best performance in 1999, when the country received the biggest amount of foreign investment. After that, the dimension' scores declined, obtaining a negative value in 2005, when foreign money was withdrawn from the country. The money started to come to the country again, but never in better rates than the period before 2005. President Evo Moralles started his mandate in 2006 and still remains in the country's presidency. Presidente Evo has a policy of nationalization of services and industries, discouraging foreign investments.

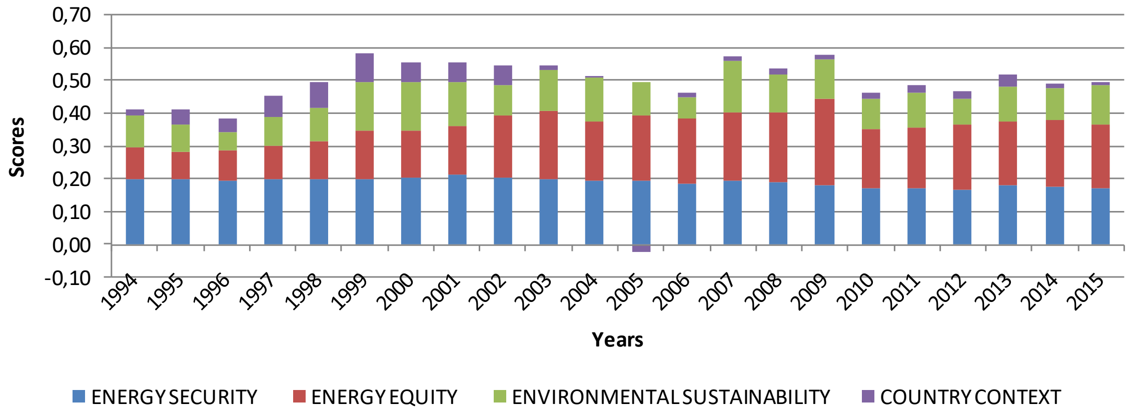

Fig 13: Energy security index and dimensions scores – Bolivia

3.2.3. Brazil

Brazil was 24% less secure in 2015, compared to the scores observed in 1994. Since 2002, Brazilian ESI continuously dropped, influenced by the great decrease in energy equity dimension' scores [*Fig 14*].

Until 2001, energy security dimension is basically the same, with no relevant increase or decrease. From 2002 on, the scores started to grow, and the period's average performance was 45% better than the previous years. The best value was reached in 2014, when energy security dimension was twice the number observed in 1994. In the period between 2002 and 2015, Brazil's energy imports decreased and the electric matrix became more diverse. The domestic oil production continuously increased. In 2009, the first oil from pre-salt region was extracted. The production expanded from 41000 barrels per day, in 2010, to one million in 2016 (Petrobras, 2018). Also, since 2004, Brazil started the commercialization of electricity with Argentina and Uruguay.

In 2002, Brazilian government created the Incentive Program for Alternative Energy Sources. The objective was to increase the participation of alternative renewable sources in electricity generation. Entrepreneurs that do not have corporate ties with generation, transmission and distribution concessionaries are privileged. Until 2016, the Program made possible a total of 2679 MW in installed capacity through the signing of 20-year contracts for the sale of energy produced for the state-owned Eletrobras (Chamber of Electric Energy Commercialization, 2018).

The period between 1994 and 2002 was good for energy equity dimension. Electricity prices were at reasonable levels for households and industry. Since then, the prices started to grow, reaching the highest values in 2011, causing the decrease of energy equity. Until 1992, electricity tariffs were regulated as service cost; in 1993, the regulation system changed to price cap. Between 1994 and 2003, the government started to implement a privatization program of generation, and T&D companies. After 2002, electricity prices for household and industry were more than 100% higher than the price in 1994. This increase was justified by the application of various charges during the decades, many of them with function duplicity, as the Energy Development Account and the Incentive Program for Alternative Energy Sources (Carção, 2011)

No relevant changes were observed in environmental sustainability dimension. The difference between the highest and the lowest score was 4%. The best score was reached in 2009. In this year it was also observed the best improvement compared to the previous year (17% of increase). CO_2 emitted per KWh generated was 37% lower than the emissions in 2008. The trend on CO_2 emissions was also the smaller.

Country context improved along the years. The difference between the worst and the best year was 135%. A constant increase was observed since 2007, due to the raise in the number of patents issued by resident and the good levels of foreign investments in the country.

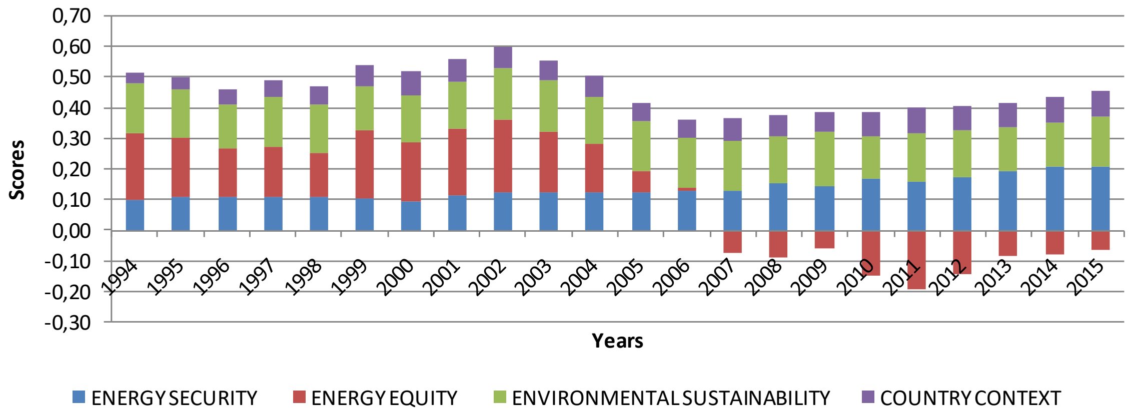

Fig 14: Energy security index and dimensions scores – Brazil

3.2.4. Chile

In 2015, Chilean ESI was 18% below the level registered in 1994. Energy equity and environmental sustainability averages in the period dropped 46% and 12%, respectively. The decline in energy equity was due to the increase in the electricity prices. In 2015, Chile emitted 89% more CO_2 per habitant, what can be explained by the great increase in the CO_2 emitted from electricity generation – more than 300%. In addition, the share of fossil fuels power plants in the electric matrix increased 14%.

Three separated periods can be analyzed in Chilean ESI's behaviour: 1994-1997, 1997-2003, and 2003-2015 [*Fig 15*]. In the first period, a small decrease is observed – 8%, due to the reduction in energy equity and environmental sustainability dimensions. From 1997 to 2003, a growth of 31% was observed. Energy equity was the dimension with the greatest increase in this period. The average between 1997 and 2003 was 50% above the average of the preceding years, due to the cheaper prices of electricity. After 2003, energy security in Chile continuously fell, mainly because of the raise in electricity prices. Environmental sustainability started to decline and, among ups and downs, never reached 2003's levels again. The worst reduction was registered in 2011; when the dimension was 24% lower than 2003, as a result of the increase in losses in electric transmission and distribution systems, and in CO_2 emission, due to the reduction of renewables in electric matrix. In this last period, energy security dimension fell marginally (8%). A small increase in energy imports and a decrease in electric matrix diversity were observed. Country context improved, induced by the good levels of foreign investments.

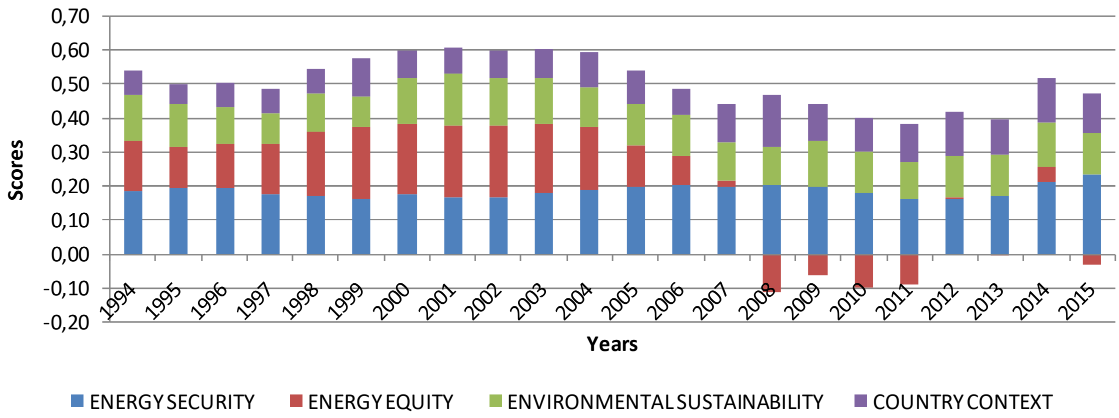

Fig 15: Energy security index and dimensions scores – Chile

3.2.5. Colombia

Compared to 1994, in 2015 Colombia worsened its ESI in 26%. The decrease in the energy equity score was the responsible for the lower values and, once again, the increase in the electricity prices lead to this reduction. All other dimensions improved in 2015, compared to 1994 [*Fig 16*].

An abrupt fall is observed from 1994 to 1995. This occurred due to the decrease in the population electricity access, recovered in the next year and continuously grew. After the recovery, in 1996, dimensions improved in general until 2001. In 2003, Ministry of Mine and Energy of Colombia launched the Indicative Plan for Expansion of Electricity

Access. The plan established the responsibilities, regulatory mechanisms and economic resources to expand the access to electricity among Colombian population. The plan is in its 5th edition (Colombian Electric Information System, 2018). Electric matrix was more diverse, but still dependent in hydropower; energy exports increased; and energy and CO_2 intensity reduced. After 2001, Colombian ESI worsened more than improved. Between 2001 and 2015, the index reduced 32%. In this period, only energy equity presented a worsening. However, it was enough to impede that the improvement in other dimensions could increase the overall security. Energy equity was impacted by the increase on electricity prices, reducing 97% of its performance in the period, compared to 2001.

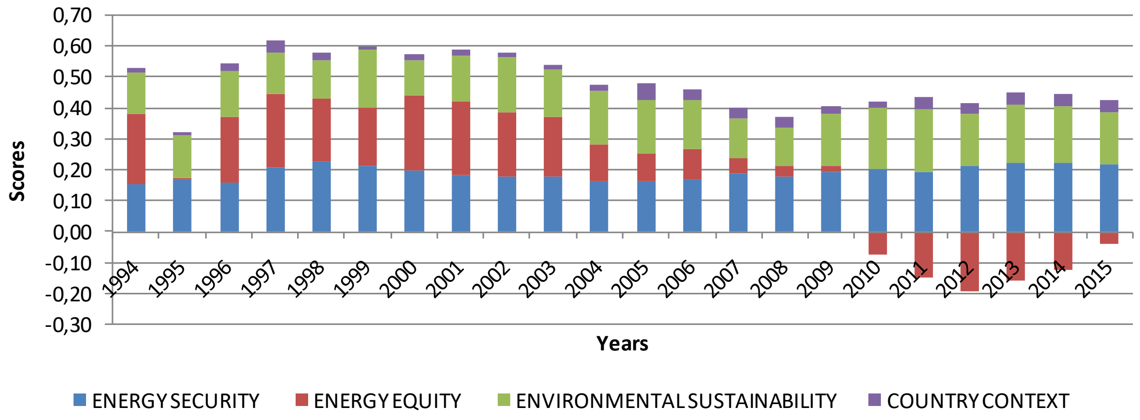

Fig 16: Energy security index and dimensions scores – Colombia

3.2.6. Ecuador

In 2015, Ecuador was slightly less secure than in 1994. Energy equity and environmental sustainability dimensions' score were smaller in 2015, compared to 1994. Fluctuations in ESI were observed during the period analyzed [*Fig 17*].

All dimensions presented a reduction in the period between 1999 and 2002. Energy security had the smallest decrease – 12%, as a consequence of the increase in the energy consumption in relation to the GDP growth. The increase in electricity prices reduced the country's energy equity in 17% in the period. Also, environmental sustainability and country context diminished their scores.

The increase observed in 2002-2008 reflected the improvement in energy security, energy equity and environmental sustainability dimensions. In this period, the primary energy and electric matrixes became more diverse. Also the country exported more energy in 2008 than in 2002, once the relation production vs. consumption is higher in 2002 than in the next period, until 2008. The GHG emission trends were optimistic, with the decrease of CO_2 emission and deforestation rates. Also, Ecuador was more energy efficient during this period, with lower values of energy intensity.

After 2008, Ecuador presented ups and downs in its energy security indexes, finally scoring 14% less in 2015. Country context is 35% smaller, due to the reduction in foreign investments. In 2007, Rafael Corrêa Delgado was elected for president and changed the economy policy of the country, deciding to reduce the payment of the debt for FMI, in order to redistribute this money for social improvement programs. As consequence, investors were recommended not to spend money in the country, so the investments decreased (Viana, 2013). Energy equity reduced 21%, as consequence of the raise in the electricity prices, both for households and industry. The energy efficiency dropped, and the losses in the transmission and distribution systems increased. Also, the country emitted more CO_2 per capita and per KWh generated. All this conveyed to a reduction in the environmental sustainability dimension.

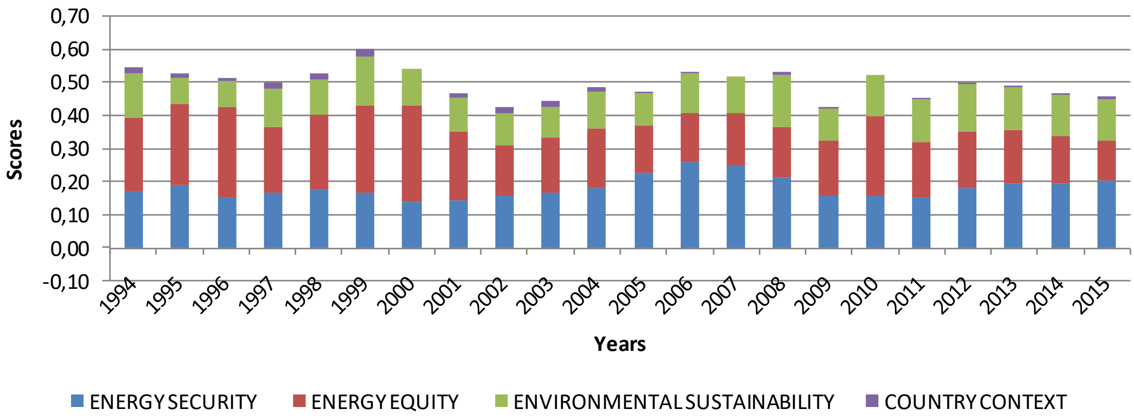

Fig 17: Energy security index and dimensions scores – Ecuador

3.2.7. Paraguay

Paraguay's ESI increased 5% [*Fig 18*]. Energy equity and sustainability are better in 2015 than in 1994, whilst energy security and country context dimensions reduced their performance' scores. In 1994, almost 62% of Paraguayan population had access to electricity. In 2015, this number was much better – 97%. Electricity prices did not change substantially during the period. The country is less energy intensive, and the transmission and distribution systems are more efficient in 2015. The electric matrix is based only in hydro power plants, which is a risk to the system, once it is not diverse. However, it guarantees that there is, virtually, no CO_2 emitted by electricity generation.

Energy security's behaviour is homogeneous across the years, with no big peaks of increase or decrease. Country context had its biggest worsening in the period between 1994 and 2000, when foreign direct investment decreased around 47%. However, the increase in remained dimensions conducted to an improvement in the ESI. The highest score was registered in 2000, when all dimensions performed well. Since 2000, energy security worsened insignificantly, with periods of increase and others of decrease. The average of the forward years is 9% below the level observed in 2000. The decrease on energy equity and environmental sustainability dimensions was the responsible for this reduction. The electricity prices rose in this period, the quality of electric transmission and distribution was poorer, and the CO_2 emitted per capita was higher. Notwithstanding, energy security and country context dimensions suggested an improvement, drove by the diversification of primary energy matrix, by the reduction on energy exports, and by the increase of foreign direct investments in the country.

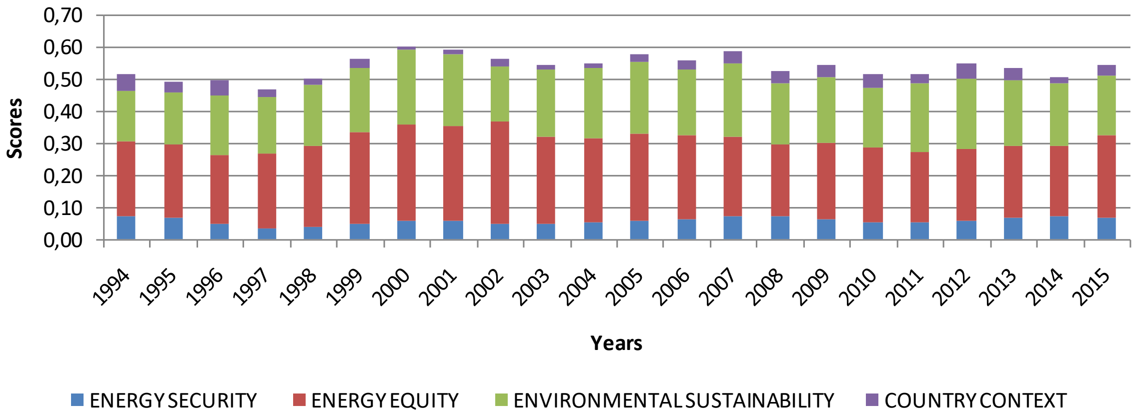

Fig 18: Energy security index and dimensions scores – Paraguay

3.2.8. Peru

In 2015, Peru's ESI was 8% less than 1994's score [*Fig 19*]. Country context is better, with higher foreign investments. Energy security dimension is also better, because the matrixes diversification and the increase in export rates. Energy equity worsened, due to the raise in electricity prices. The increase in CO_2 emissions and in the losses in T&D systems drove to a reduction in the environmental sustainability dimension.

In 1995 an increase was observed, and the levels were maintained similar until 2011, when a great increasing peak was registered. In 1994, Peru had the second worst electricity access rate in the region, just behind Bolivia. However, the rate of improvement was better in Bolivia than in Peru, thus energy equity' score was the lowest one in this year, influencing the performance over the next years.

From 1995 until 2010, no relevant changes occurred in energy security dimension, neither to environmental sustainability. The diversity in energy matrix increased more than in the electric, and Peru remained as an energy export country. The energy intensity lingered virtually the same in the period, and CO_2 emissions from electricity generation slightly increased.

In 2011, energy equity presented a great increase due to the good rate of improvement in access to electricity, compared to the rates registered for the other years. Peru always presented the worst rates on access to electricity in the region. Just in 2013 the country achieved the 90%, moving up one position in the ranking, ahead only of Bolivia.

Since 2011, Peru's ESI declined, mainly because of the expansion of electricity access that was more homogenous along the years and the price of electricity rose a little. Environmental sustainability and energy security dimensions were improved. The diversity of electric matrix increased, as well as energy exports.

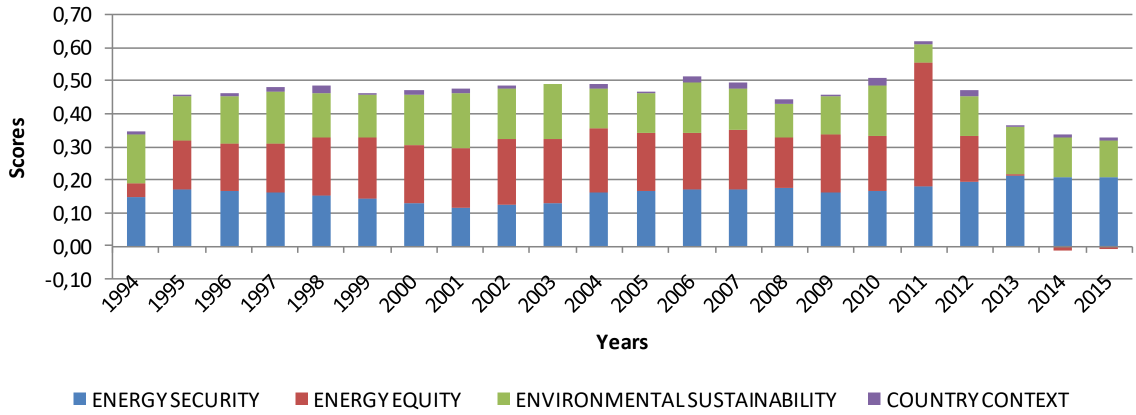

Fig 19: Energy security index and dimensions scores – Peru

3.2.9. Uruguay

Uruguay worsened its energy security in 2015, compared to 1994's [*Fig 20*]. All dimensions presented variations along the years. The best score was obtained in 2003; and the worst in 2011. In the period between 2003 and 2011, energy security index decrease 32%, whereas energy equity and environmental dimensions reduced their scores. Notwithstanding, energy security and country context dimensions expanded during the mentioned period. The electricity prices were higher, as the CO_2 emission rates. The primary energy and electric matrixes were more diverse, and a little increase in foreign direct investment occurred.

After 2011, energy security index grew 41%, reflected by the recovery in all dimensions. Diversity of primary energy and electric matrixes increased, energy imports reduced, and the country consumed less energy per GDP. Also, the average of CO_2 emission in the next years was lower than the rates emitted in 2011. It can be justified by the increase of renewables' share in electric matrix, especially wind power, which increased more than 400% in the last four years.

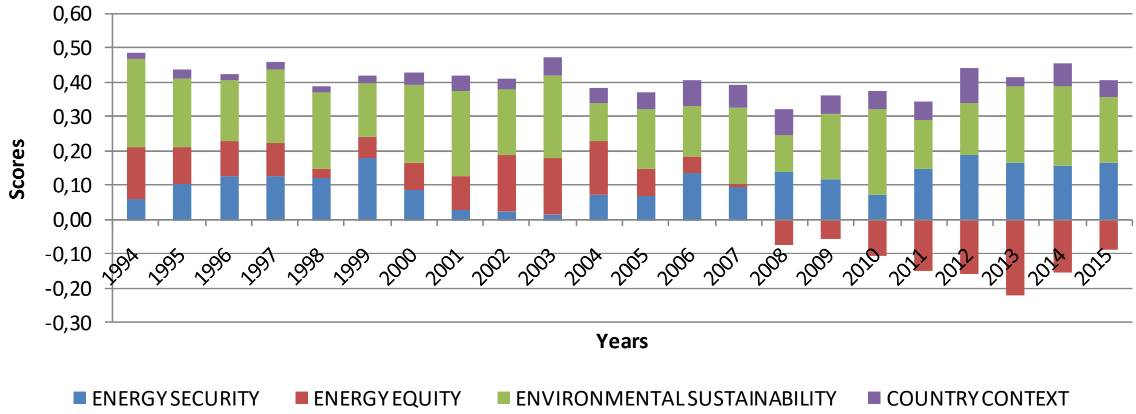

Fig 20: Energy security index and dimensions scores – Uruguay

3.2.10. Venezuela

In 2015, Venezuela presented almost the same level of energy security observed in 1994, only 6% higher. Along the years, dimensions scores fluctuated between better and worse values [*Fig 21*]. The worst performance was registered in 2005; whilst the best was in 2011.

In 2013, energy security dimension registered its best mark. In this year, diversity's rate of primary energy and electric matrixes performed well and the country managed properly the energy demand to generate GDP growth. The worst score in this dimension was observed in 2010, after the decrease started in 2007, caused by the reduction in energy exports and in the diversity of the primary energy matrix. In 1999 and 2001, ex-President Hugo Chavez established a new regulatory framework transferring to the state the control of oil activities and shares of Company Petróleos de Venezuela S.A.. Between 2001 and 2015, Venezuelan oil production decreased around 672000 barrels. There are mainly three reasons for this reduction: "the loss of technical capacity of the state-owned company after massive layoffs in 2003; the decline in the presence of service providers; and the low level of investments in exploration and production" (Vitto, 2017, p. 8)

The best score of energy equity dimension was in 2011; and the worst, in 1995.

Between these years, an increase of 24% was observed. Electricity prices were cheaper and the access to electricity services increased.

2003 was the worst environmental performance year, due to the high levels of CO_2 emitted, losses in the electric transmission and distribution systems, and energy intensity. In 2011, the low emission rates of CO_2 per capita and per GDP, in addition to small energy intensity, contributed to the achievement of the best environmental performance.

Country context is a sensitive dimension, due to political framework installed in the country along the years. In 1997, Venezuela received the greatest amount of foreign investment. Since then, the sum of money is decreasing, even occurring withdraw of investment in 2009. After 2009, money started to enter in the country again, but not in relevant levels anymore.

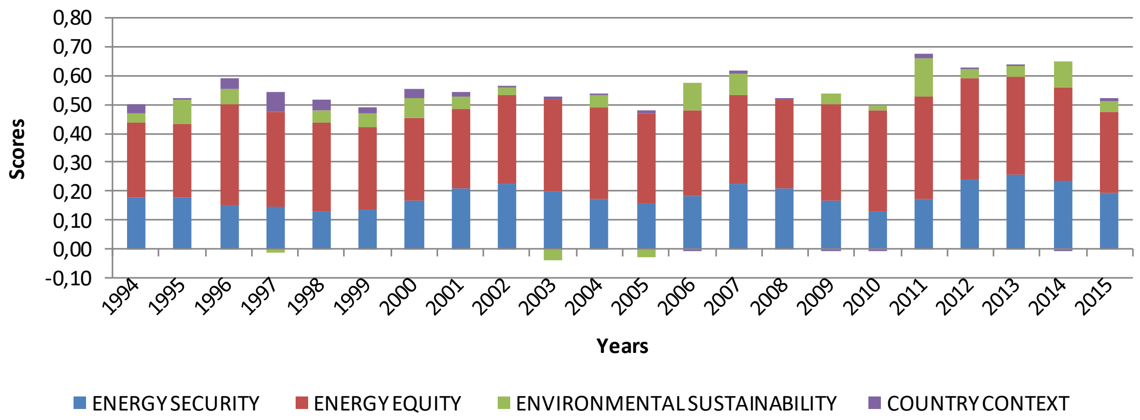

Fig 21: Energy security index and dimensions scores – Venezuela

3.3. Regional profile – South America vs. Top 10 countries (2007-2015)

Compared to the top 10 countries, ranked by the Energy Trilemma in 2016, South America always presented the lowest scores. Switzerland (SWZ) and Sweden (SWD) were the countries better ranked in the period analyzed [*Fig 22*]. On average, South America´s ESI was 50% lower than the best positioned country, and 40% below the total mean.

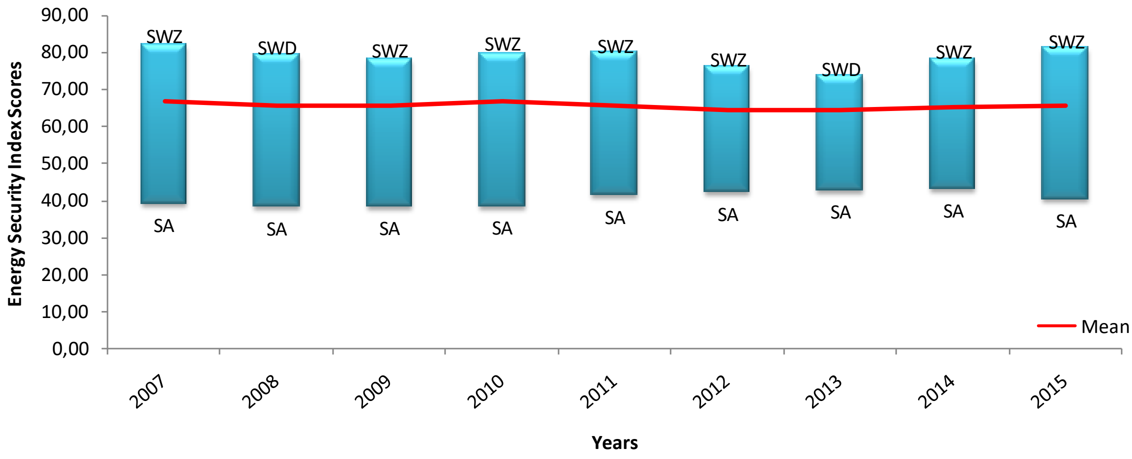

Fig 22: Best and worst energy security index – Top 10 countries and South America

3.3.1. Energy security dimension

South America was not the best country in this dimension, but it was not the worst either. Finland (FIN), Switzerland (SWZ) and New Zealand (NZE) were the countries in first positions during the period; Netherlands (NTH) and Norway (NOR), the countries on last rank [*Fig 23*]. From 2011 until 2014, South America was close to the mean. In general, the region is 19% better than the last score's mean, but 33% worse than the mean of the series. In average, the best scores are 78% better than energy security dimension score of South America.

The region presented the worst marks for resilience category's indicators: diversity of electricity generation and preparedness. As discussed, electric matrix in South America is based mostly on hydro and fossil fuel thermo power plants. And the availability of scientist, engineers and higher education is well below developed countries' levels.

However, South American was above the average for the category of security of supply and energy delivery. This is mainly due to the fact that the region is an energy exporter, losing only for Norway.

Finland presented the most diverse electricity matrixes during the period, with renewables increasing their shares in 70% during the period. In 2006, Energy Department of Ministry of Trade and Industry of Finland emitted the Outline of the Energy and Climate Policy for the Near Future. Subsidies and RD&D programs to promote the use of renewables both in primary energy and electric matrixes were proposed (Energy Department, 2006). The Strategy was reviewed in 2008 and 2013. The last report described the progress made in evaluating and improving administrative procedures to remove regulatory and non-regulatory barriers to the development of renewable energy. According to this, the working group created to promote wind power resulted in the removal of barriers and restrictions from various administrative areas. The mechanisms supported the cooperation between issues as land use, transport, noise problems, and environmental impacts. The report also mentioned the efforts to facilitate small-scale electricity production, through programmes of taxation and simplification of small-scale production process (Energy Department, 2016) .

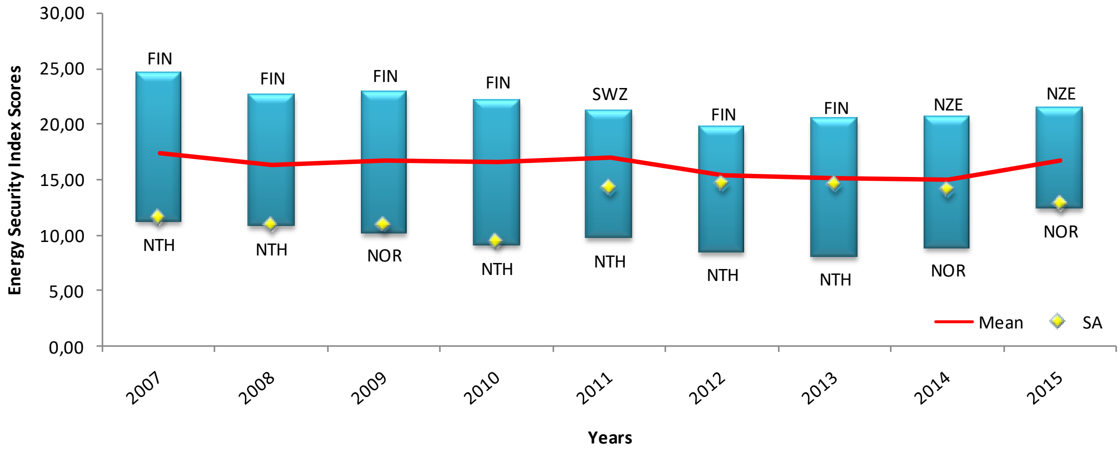

Fig 23: Best and worst in energy security dimension – Top 10 countries and South America

3.3.2. Energy equity dimension

Despite having the best electricity prices, South America presented the worst scores for the other dimension's indicators [*Fig 24*]. The access to electricity is 100% for all the top ten countries; South American levels are still between 95%. Also, the access to clean fuels for cooking is almost 100% for the developed countries; South American did not reach the 90% yet. At last, the quality of electricity supply of the region is around 4, in a scale of 1-7; top 10 averages are 6.

Denmark was the country with the best scores over the years analyzed, due to the best quality of electricity supply. Power shortages have not caused consumer outages in Denmark in the past years; and "outages at the distribution level are relatively stable at around 20-30 minutes per average per consumer per year (Energinet, 2017, p. 16).

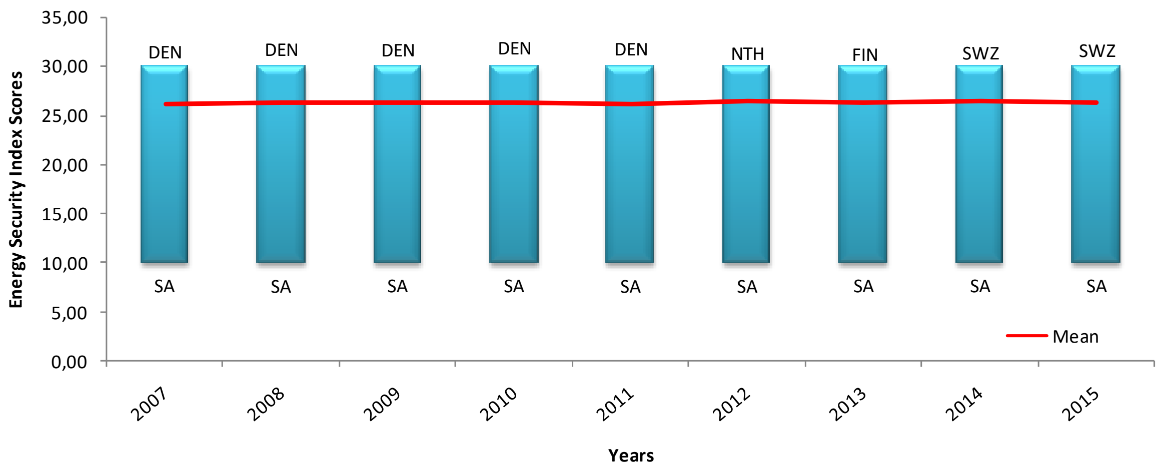

Fig 24: Best and worst in energy equity dimension – Top 10 countries and South America

3.3.3. Environmental sustainability dimension

South America's environmental sustainability performed well compared to the top 10 [*Fig 25*]. Most of time near to the mean, it figured better in 2009 and 2010. The region presented good values for energy intensity and CO_2 emissions indicators, due to the great share of hydropower in the electric matrix. Also, the trend in forest change best mark was South American. However, it is not good indicator to be compared between top 10 and the region, as South America have relevant forest coverage area and deforestation reached high ratios in the last decades. It is expected that the reduction trend of deforestation in South America be higher than in the top 10 countries.

Switzerland ranked at the best position in the entire period, except in 2013, when Sweden presented the greatest score. Switzerland is the country less energy intensive, meaning that it need lower energy consumption levels to generated wealth. This is due to energy efficiency programmes promoted by Swiss government. The Swiss Federal Office of Energy supports the development, distribution and use of technologies aimed at enhancing energy efficiency. Researches on diverse areas are also conducted in the country and supported by the state, such as fuel cells, cogeneration, electrical appliances, and energy labels (Swiss Federal Office of Energy, 2018)

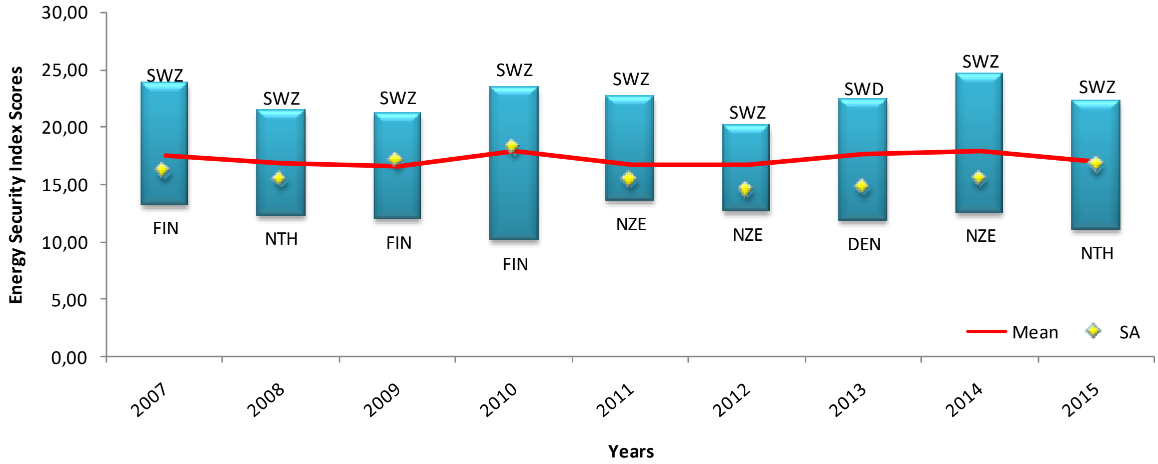

Fig 25: Best and worst in environmental sustainability dimension – Top 10 countries and South America

3.3.4. Country context dimension

As expected, South America presented the worst country context' scores [*Fig 26*]. All indicators were the lowest, except for FDI & technology transfer (2010, 2011, and 2012), and for foreign direct investment, which the region was always better than one of the top 10.

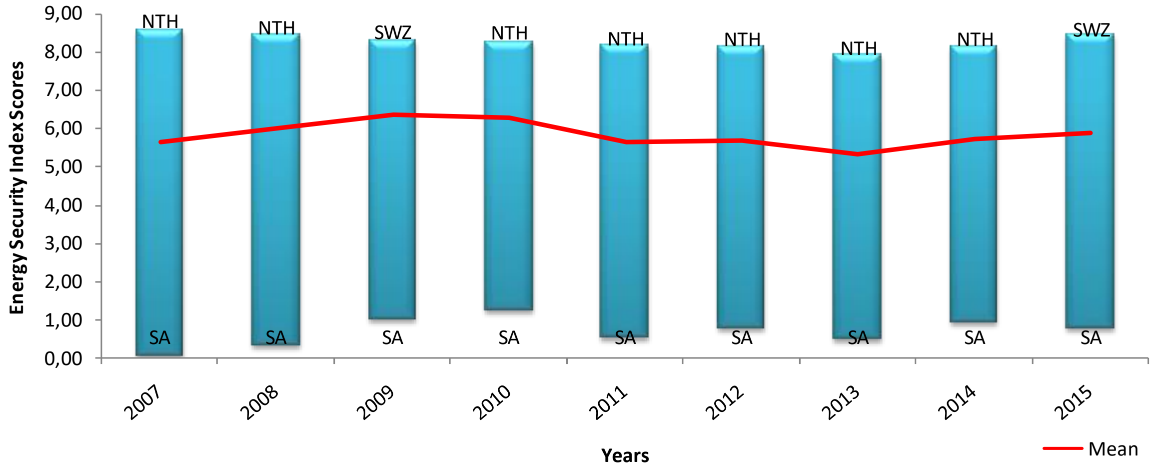

Fig 26: Best and worst in country context dimension – Top 10 countries and South America

CONCLUSIONS

Energy security in South America, as a whole, enhanced over the years. The improved distribution of electricity access to population, the decrease of energy imports and the diversification of the energy mix, with the inclusion of new renewables sources, besides large hydropower, contributed to the increase in ESI performance in the period analysed. Also, the region, in general, is obtaining more foreign investments.

Despite the increase of renewables' share in the mix, South America economy grows under the shadow of green house gas emissions' increase, a consequence of the insufficient level of investments in energy efficiency programmes and in new technologies policies.

As expected, Chile and Argentina ranked in the first position over the years. Mainly because of the fact that they already started from higher levels and not because they improved performance in the ESI. In fact, Chile worsened its performance by 18%.

Bolivia was the country with the best improvement observed. However, it was mostly due to the fact that the country started from the worst levels in 1994. Bolivia frequently scored in the worst positions for all dimensions along the period analysed.

Venezuela is the country presenting the best scores in energy equity, due to the electricity prices, and also the country that most improved it scores in environmental sustainability dimension. Yet, it is not the most environmental sustainable in the region, as it presents high levels of CO_2 emitted by the energy sector. Thus, Paraguay surged as the most environmental sustainable country, due to its energy mix that is virtually only composed by hydropower.

Some criticism must be done to the electricity price indicator. In the form that was applied in this study, it does not reflect the service affordability to the population. It may be better used if it considers the purchase power or inflation. Electricity prices in Venezuela can be the cheapest ones, but it does not mean that population is available to pay for it.

The good combination of foreign investment and initiatives that enable R&D made Uruguay the country that increased the most in the country context, i.e. 188%.

As expected, when compared to the top ten countries ranked by Energy Trilemma Report 2016, South America always ranked last. The difference between investments made by the developed countries and by South America in new technologies, energy efficiency policies and programmes, and the stability of politic and economical framework can be clearly observed in the gaps between scores.

In sum, this study is partially aligned with the conclusions from the Energy Trilemma Report 2016. The report analyzed Latin America and Caribbean and observed that the region's strong reliance on hydropower is a risk factor for energy security, and suggested the diversification of the energy matrix. Trilemma also suggested the regional integration of the transmission and distribution systems as one of the initiatives that should be implemented to increase region's resilience. On the other hand, the best country ranked by Trilemma 2016 was Denmark. However, in this study, when comparing South America with top ten Trilemma's countries, Switzerland and Sweden were the best, due to the changes made in the methodology. This reinforces the idea that little differences in methodologies result in different energy security performances.

The top ten countries ranked by Energy Trilemma 2016 were mainly European Member-States. In Europe, the EC's 2020 and 2030 goals boost the development of energy policies and programmes by each country, adapted to their realities. South America should follow the same line of policy-making, and work harder in promoting regional agreements to improve its energy security performance, either by integrating its T&D systems, as mentioned by other authors, or by cooperating to diverse its matrixes and to take better advantage of the potential that the region has for renewables sources, or by exchanging knowledge about energy efficiency programmes.

Future works on detailed analysis of energy security dimensions and indicators should be conducted to develop, or to adapt, performance evaluation methodologies that reflect the specificities of South America. This new index should have the ability to create scenarios according to the energy policies that can be implemented in each country. The trade-off relations between indicators should also be analyzed, as well as the consequences of the improvement of a specific country in the region's energy security performance. This index should be developed with the purpose of acting as an energy policy-making tool.

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ANNEXES

ANNEX 1 – Scores of South American Countries

Table 10: Energy Security Index Scores: South American Countries

	Arg	Bol	Bra	Chi	Col	Ecu	Par	Per	Uru	Ven
1994	53,91	37,74	50,25	54,96	48,59	48,99	48,46	40,88	50,00	44,59
1995	55,41	40,19	53,09	56,05	43,38	50,10	47,55	48,32	50,42	47,38
1996	56,60	39,60	50,84	57,18	52,44	48,04	49,58	49,90	51,75	53,94
1997	56,83	42,09	54,21	54,30	57,26	48,39	46,93	50,28	53,72	52,23
1997	60,02	44,88	52,79	59,80	53,95	51,34	47,70	50,20	50,00	54,58
1999	60,40	52,72	58,40	62,11	57,56	57,54	53,48	50,56	52,90	52,51
2000	54,83	50,72	55,80	62,68	57,24	52,12	57,56	49,71	52,71	55,14
2001	56,24	50,72	59,57	64,00	57,75	44,66	58,09	48,85	50,95	55,27
2002	66,88	50,39	61,79	62,81	56,24	45,57	55,20	49,37	47,49	59,10
2003	67,32	49,06	57,51	63,24	51,90	46,77	56,37	47,93	50,55	54,69
2004	65,20	47,24	57,08	66,20	50,22	54,46	58,92	52,05	48,71	56,75
2005	67,83	44,73	54,37	62,59	55,52	53,18	60,89	54,47	52,23	51,63
2006	66,04	41,01	50,76	58,62	54,29	53,46	58,08	55,34	58,40	54,88
2007	63,15	51,07	51,62	60,40	53,95	55,85	60,15	56,24	59,70	58,65
2008	63,99	49,56	54,72	60,17	54,79	60,39	59,58	56,48	57,10	54,49
2009	66,57	48,64	58,24	63,04	58,44	50,78	59,83	53,76	62,37	54,37
2010	66,54	46,05	58,53	63,14	60,35	56,27	57,90	64,64	63,66	51,25
2011	64,28	46,08	58,39	63,25	60,05	55,56	59,43	58,85	60,14	60,40
2012	61,52	40,74	59,06	64,84	55,18	58,10	59,23	59,55	63,19	55,51
2013	59,50	46,38	61,36	63,89	61,58	56,53	56,22	50,80	62,26	57,50
2014	57,57	41,31	62,42	70,25	59,40	55,16	53,58	46,32	63,97	62,57
2015	58,63	43,86	64,89	68,90	60,15	55,32	55,00	44,38	62,16	53,95

Table 11: Energy Security Dimension Scores: South American Countries (1994 as base year)

	Arg	Bol	Bra	Chi	Col	Ecu	Par	Per	Uru	Ven
1994	0,21	0,20	0,10	0,18	0,16	0,17	0,07	0,15	0,06	0,18
1995	0,20	0,20	0,11	0,19	0,17	0,19	0,06	0,17	0,10	0,18
1996	0,19	0,20	0,11	0,19	0,16	0,15	0,05	0,17	0,13	0,17
1997	0,21	0,20	0,11	0,17	0,21	0,17	0,03	0,17	0,12	0,16
1997	0,21	0,20	0,11	0,17	0,23	0,18	0,03	0,16	0,12	0,15
1999	0,19	0,20	0,11	0,16	0,21	0,17	0,05	0,15	0,18	0,14
2000	0,18	0,20	0,10	0,17	0,20	0,14	0,05	0,13	0,09	0,17
2001	0,18	0,21	0,12	0,17	0,18	0,14	0,05	0,12	0,03	0,20
2002	0,17	0,21	0,12	0,16	0,18	0,16	0,05	0,13	0,03	0,22
2003	0,17	0,20	0,13	0,18	0,18	0,17	0,05	0,13	0,02	0,19
2004	0,17	0,20	0,13	0,19	0,16	0,18	0,05	0,16	0,08	0,17
2005	0,19	0,20	0,13	0,20	0,16	0,23	0,06	0,17	0,07	0,16
2006	0,20	0,19	0,13	0,20	0,17	0,26	0,06	0,17	0,13	0,19
2007	0,19	0,20	0,13	0,20	0,19	0,25	0,07	0,17	0,09	0,23
2008	0,19	0,19	0,15	0,20	0,18	0,21	0,07	0,18	0,14	0,20
2009	0,19	0,18	0,15	0,20	0,20	0,16	0,07	0,17	0,12	0,16
2010	0,19	0,17	0,17	0,18	0,21	0,16	0,06	0,16	0,08	0,12
2011	0,18	0,17	0,16	0,16	0,20	0,16	0,06	0,18	0,15	0,17
2012	0,17	0,17	0,17	0,16	0,21	0,18	0,06	0,20	0,19	0,24
2013	0,16	0,18	0,20	0,17	0,22	0,19	0,07	0,22	0,17	0,26
2014	0,15	0,18	0,21	0,21	0,23	0,20	0,07	0,21	0,16	0,24
2015	0,16	0,17	0,21	0,23	0,22	0,20	0,06	0,21	0,17	0,21

Table 12: Energy Equity Dimension Scores: South American Countries (1994 as base year)

	Arg	Bol	Bra	Chi	Col	Ecu	Par	Per	Uru	Ven
1994	0,16	0,10	0,22	0,15	0,23	0,22	0,24	0,04	0,15	0,26
1995	0,17	0,08	0,20	0,12	0,00	0,25	0,23	0,15	0,11	0,25
1996	0,16	0,09	0,16	0,13	0,21	0,27	0,22	0,14	0,10	0,35
1997	0,12	0,10	0,16	0,15	0,24	0,20	0,23	0,15	0,10	0,33
1997	0,15	0,11	0,15	0,19	0,20	0,22	0,26	0,18	0,03	0,30
1999	0,15	0,15	0,22	0,21	0,19	0,26	0,29	0,18	0,06	0,29
2000	0,15	0,14	0,19	0,21	0,24	0,29	0,30	0,18	0,08	0,29
2001	0,17	0,15	0,22	0,21	0,24	0,21	0,30	0,18	0,10	0,28
2002	0,33	0,19	0,24	0,21	0,20	0,15	0,32	0,20	0,17	0,31
2003	0,32	0,21	0,20	0,20	0,19	0,17	0,27	0,19	0,17	0,32
2004	0,31	0,18	0,16	0,18	0,12	0,18	0,27	0,19	0,15	0,32
2005	0,29	0,20	0,07	0,12	0,09	0,14	0,28	0,17	0,08	0,31
2006	0,31	0,20	0,01	0,09	0,10	0,15	0,26	0,17	0,05	0,30
2007	0,26	0,21	-0,07	0,02	0,05	0,16	0,25	0,18	0,01	0,31
2008	0,23	0,21	-0,09	-0,11	0,03	0,15	0,23	0,15	-0,07	0,31
2009	0,23	0,26	-0,06	-0,06	0,02	0,17	0,24	0,17	-0,05	0,33
2010	0,26	0,18	-0,14	-0,10	-0,07	0,24	0,24	0,17	-0,10	0,35
2011	0,26	0,19	-0,19	-0,09	-0,15	0,17	0,22	0,37	-0,15	0,35
2012	0,25	0,20	-0,14	0,00	-0,19	0,17	0,23	0,14	-0,16	0,35
2013	0,27	0,19	-0,08	0,00	-0,16	0,17	0,22	0,00	-0,22	0,34
2014	0,29	0,20	-0,08	0,04	-0,12	0,14	0,22	-0,01	-0,15	0,33
2015	0,27	0,20	-0,06	-0,03	-0,04	0,12	0,26	-0,01	-0,09	0,28

Table 13: Environmental Sustainability Dimension Scores: South American Countries (1994 as base year)

	Arg	Bol	Bra	Chi	Col	Ecu	Par	Per	Uru	Ven
1994	0,10	0,10	0,16	0,14	0,13	0,14	0,16	0,15	0,26	0,03
1995	0,10	0,08	0,16	0,13	0,14	0,08	0,16	0,13	0,20	0,09
1996	0,10	0,05	0,15	0,11	0,15	0,08	0,19	0,15	0,18	0,05
1997	0,11	0,09	0,17	0,09	0,13	0,12	0,17	0,16	0,21	-0,01
1997	0,11	0,10	0,15	0,11	0,13	0,11	0,19	0,13	0,22	0,04
1999	0,10	0,15	0,14	0,09	0,18	0,15	0,20	0,13	0,15	0,05
2000	0,08	0,15	0,15	0,14	0,12	0,11	0,23	0,16	0,23	0,07
2001	0,13	0,14	0,15	0,15	0,15	0,10	0,22	0,17	0,25	0,04
2002	0,11	0,09	0,17	0,14	0,18	0,10	0,17	0,15	0,19	0,03
2003	0,10	0,12	0,17	0,14	0,15	0,09	0,21	0,17	0,24	-0,03
2004	0,08	0,13	0,15	0,12	0,17	0,11	0,22	0,12	0,11	0,04
2005	0,10	0,10	0,16	0,13	0,17	0,10	0,22	0,12	0,17	-0,02
2006	0,10	0,07	0,16	0,12	0,16	0,12	0,21	0,15	0,15	0,09
2007	0,08	0,16	0,16	0,11	0,13	0,11	0,23	0,13	0,22	0,07
2008	0,10	0,12	0,15	0,11	0,12	0,16	0,19	0,10	0,11	0,00
2009	0,12	0,12	0,18	0,13	0,17	0,10	0,21	0,12	0,19	0,04
2010	0,10	0,09	0,14	0,12	0,20	0,13	0,19	0,15	0,25	0,02
2011	0,10	0,10	0,16	0,11	0,20	0,13	0,21	0,06	0,14	0,13
2012	0,11	0,08	0,15	0,12	0,17	0,15	0,22	0,12	0,15	0,03
2013	0,10	0,11	0,14	0,12	0,19	0,13	0,20	0,14	0,22	0,04
2014	0,10	0,10	0,14	0,13	0,18	0,13	0,20	0,12	0,23	0,09
2015	0,09	0,12	0,16	0,12	0,17	0,13	0,19	0,11	0,19	0,04

Table 14: Country Context Dimension Scores: South American Countries (1994 as base year)

	Arg	Bol	Bra	Chi	Col	Ecu	Par	Per	Uru	Ven
1994	0,06	0,02	0,04	0,07	0,02	0,02	0,05	0,01	0,02	0,03
1995	0,06	0,04	0,04	0,06	0,01	0,01	0,03	0,00	0,03	0,01
1996	0,09	0,04	0,05	0,07	0,03	0,01	0,05	0,01	0,02	0,04
1997	0,08	0,06	0,05	0,07	0,04	0,02	0,03	0,01	0,02	0,07
1997	0,07	0,08	0,06	0,07	0,03	0,02	0,02	0,02	0,02	0,04
1999	0,12	0,09	0,07	0,12	0,01	0,02	0,03	0,00	0,02	0,02
2000	0,09	0,06	0,08	0,08	0,02	0,00	0,01	0,01	0,04	0,03
2001	0,05	0,06	0,07	0,08	0,02	0,01	0,02	0,01	0,05	0,02
2002	0,06	0,06	0,07	0,09	0,02	0,02	0,03	0,01	0,03	0,00
2003	0,06	0,01	0,06	0,09	0,01	0,02	0,02	-0,01	0,05	0,01
2004	0,06	0,00	0,07	0,11	0,02	0,02	0,02	0,01	0,04	0,01
2005	0,08	-0,02	0,06	0,10	0,05	0,01	0,02	0,01	0,05	0,01
2006	0,08	0,01	0,06	0,08	0,03	0,00	0,03	0,02	0,08	0,00
2007	0,07	0,02	0,07	0,11	0,03	0,00	0,04	0,02	0,06	0,01
2008	0,07	0,02	0,07	0,15	0,03	0,01	0,04	0,01	0,07	0,00
2009	0,04	0,01	0,06	0,11	0,03	0,00	0,04	0,00	0,06	-0,01
2010	0,05	0,02	0,08	0,10	0,02	0,00	0,04	0,02	0,05	0,00
2011	0,05	0,02	0,08	0,12	0,04	0,00	0,03	0,01	0,05	0,01
2012	0,06	0,02	0,08	0,13	0,04	0,00	0,05	0,02	0,10	0,01
2013	0,05	0,04	0,08	0,10	0,04	0,00	0,04	0,00	0,03	0,00
2014	0,03	0,01	0,08	0,13	0,04	0,00	0,02	0,01	0,07	0,00
2015	0,04	0,01	0,08	0,12	0,04	0,01	0,03	0,01	0,05	0,01

ANNEX 2 – Scores of Top 10 Countries and South America

Table 15: Energy Security Index Scores: Top 10 Countries and South America

	Den	Swz	Swd	Nth	Ger	Fra	Nor	Fin	Nze	Aus	SA
2007	69,26	81,91	76,04	62,40	71,56	68,13	65,00	73,25	57,62	69,97	37,64
2008	65,35	76,67	79,16	60,91	70,35	68,14	65,87	75,99	50,57	70,41	36,66
2009	66,66	77,97	76,91	62,14	71,03	69,52	62,40	70,69	54,94	73,48	38,91
2010	69,86	79,85	78,78	59,99	73,26	73,21	65,01	69,22	55,49	72,15	38,81
2011	68,37	80,01	74,49	61,48	69,30	69,28	65,47	70,78	49,94	70,02	40,02
2012	67,15	76,03	72,15	60,00	68,03	65,63	63,98	71,35	52,44	69,91	39,80
2013	64,06	73,54	73,85	59,67	69,28	65,86	63,74	70,10	58,34	68,05	39,72
2014	68,13	78,15	70,10	62,54	69,05	64,56	62,70	72,60	58,29	68,37	40,35
2015	66,77	81,25	71,85	61,70	68,20	66,06	65,85	74,60	60,49	66,89	40,14

Table 16: Energy Security Dimension Scores: Top 10 Countries and South America

	Den	Swz	Swd	Nth	Ger	Fra	Nor	Fin	Nze	Aus	SA
2007	16,98	22,49	22,36	11,16	18,70	16,22	12,55	24,61	19,99	14,31	16,98
2008	15,11	19,26	21,57	10,77	18,37	16,34	11,48	22,61	16,89	16,34	15,11
2009	17,26	19,06	21,32	12,14	18,47	17,86	10,20	22,87	16,30	17,36	17,26
2010	19,08	19,57	21,10	9,02	17,90	19,13	10,90	22,12	15,87	17,40	19,08
2011	17,42	21,18	21,00	9,68	17,58	18,63	14,22	19,89	15,39	17,67	17,42
2012	16,30	19,10	16,22	8,44	17,60	16,19	10,07	19,72	16,25	14,64	16,30
2013	17,86	16,78	16,15	8,05	17,91	14,90	8,64	20,46	17,21	12,90	17,86
2014	15,43	16,53	15,57	11,59	16,10	12,39	8,87	20,34	20,61	12,80	15,43
2015	14,92	20,72	17,35	13,01	17,57	16,94	12,38	21,29	21,37	15,62	14,92

Table 17: Energy Equity Dimension Scores: Top 10 Countries and South America

	Den	Swz	Swd	Nth	Ger	Fra	Nor	Fin	Nze	Aus	SA
2007	16,98	22,49	22,36	11,16	18,70	16,22	12,55	24,61	19,99	14,31	16,98
2008	15,11	19,26	21,57	10,77	18,37	16,34	11,48	22,61	16,89	16,34	15,11
2009	17,26	19,06	21,32	12,14	18,47	17,86	10,20	22,87	16,30	17,36	17,26
2010	19,08	19,57	21,10	9,02	17,90	19,13	10,90	22,12	15,87	17,40	19,08
2011	17,42	21,18	21,00	9,68	17,58	18,63	14,22	19,89	15,39	17,67	17,42
2012	16,30	19,10	16,22	8,44	17,60	16,19	10,07	19,72	16,25	14,64	16,30
2013	17,86	16,78	16,15	8,05	17,91	14,90	8,64	20,46	17,21	12,90	17,86
2014	15,43	16,53	15,57	11,59	16,10	12,39	8,87	20,34	20,61	12,80	15,43
2015	14,92	20,72	17,35	13,01	17,57	16,94	12,38	21,29	21,37	15,62	14,92

Table 18: Environmental Sustainability Dimension Scores – Top 10 and South America

	Den	Swz	Swd	Nth	Ger	Fra	Nor	Fin	Nze	Aus	SA
2007	15,73	23,75	18,25	13,42	18,00	18,15	17,77	13,23	17,39	20,91	16,06
2008	13,58	21,34	20,38	12,32	17,13	17,24	18,64	16,62	13,69	19,04	15,38
2009	12,04	21,09	18,14	12,48	17,22	16,78	16,46	11,99	18,42	20,24	16,97
2010	14,35	23,35	20,74	13,38	19,68	19,09	18,43	10,11	19,12	20,01	18,08
2011	14,49	22,65	17,15	14,39	17,75	17,05	17,04	15,72	13,59	17,52	15,31
2012	15,90	20,11	19,66	13,47	16,84	15,65	18,75	16,24	12,68	20,13	14,47
2013	11,85	21,42	22,32	14,31	18,82	17,94	20,17	13,86	17,45	20,73	14,71
2014	17,16	24,55	20,25	13,45	19,82	19,34	18,09	15,48	12,57	20,96	15,42
2015	16,59	22,13	19,19	11,05	16,60	15,98	17,81	17,20	15,13	17,54	16,58

Table 19: Country Context Dimension Scores – Top 10 and South America

	Den	Swz	Swd	Nth	Ger	Fra	Nor	Fin	Nze	Aus	SA
2007	6,64	6,44	6,82	8,56	5,30	4,36	5,70	6,18	6,22	5,98	0,06
2008	6,75	6,44	7,81	8,43	5,48	4,97	6,52	7,07	6,26	5,90	0,35
2009	7,44	8,27	8,01	8,14	5,89	5,19	6,57	5,99	6,71	6,52	1,02
2010	6,51	7,37	7,63	8,26	6,12	5,58	6,74	7,16	7,11	5,31	1,26
2011	6,55	6,61	7,25	8,19	4,88	4,54	5,96	5,73	6,34	5,47	0,54
2012	5,20	7,00	7,17	8,13	5,20	4,38	6,35	6,24	6,69	5,51	0,76
2013	5,10	5,80	6,74	7,95	5,31	3,92	5,87	5,81	6,60	5,13	0,51
2014	5,93	7,09	6,05	8,13	5,58	4,00	5,98	6,91	7,25	5,16	0,94
2015	5,86	8,43	6,60	8,39	5,79	4,39	6,33	6,68	6,62	4,73	0,79