ASSESSMENT OF ENERGY SECURITY IN THE ELECTRICITY INDUSTRY VALUE CHAIN: 10 SELECTED LATIN AMERICAN COUNTRIES

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Abstract

When technological advances were reached during the XIX century, energy started to be transformed into electricity through the use of different energy resources, technologies and processes. The importance of electricity supply in terms of energy security emerged from the fact that it is a basic service which has to meet demand requirements in real time and therefore must be guaranteed through controlling the factors that may affect the stability in supplying the service, in addition electricity industry by its own nature is connected to the energy resource system. Beside the electricity industry value chain, we found different processes or systems such as electricity generation, transmission and distribution.

Although there is an extensive literature regarding security of energy supply, still there is no prior study that undertakes energy security for the electricity industry through considering the electricity industry's value chain and the core indicators that can influence negatively the continuity of electricity supply. There is a need for accomplishing new research methodologies in different energy security fields. Based on these conditions and after researching and analyzing various textbooks, papers and journal articles, our research objective is to define and develop a proper approach for evaluating energy security in the electricity industry value chain through considering ten different Latin American countries: Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, and Peru.

Key words: Energy security; electricity industry value chain; indicators for security of electricity supply, electrical infrastructure efficiency.

1. Introduction

In ancient times the machineries used in the production of goods or the provision of services were driven by manual processes. As technological advances were reached, automation of productive processes took place by means of electricity [51]. The electricity industry became in the pillar which supports the development of human and economic activities [26]. It is important in terms of energy security and because of the supply of this service needs to be guaranteed without interruptions and at affordable price [20]. The importance of electricity supply in terms of energy security is because it is a basic service which has to meet demand requirements in real time and therefore must be guaranteed through controlling the factors that can affect stability on supplying the service [39].

The electricity service plays a significant role in the society's economy since it is vital to achieve a certain standard of living and cover certain daily needs [2]. Due to its importance there is a need to ensure security of supply for both of them. This situation has made that energy security obtain importance among political leaders and with strong impetus after California electricity crisis [20; 35]. It has been addressed within their policies with the objective to strengthen nation's economic growth and cover the provision of energy by means of combustibles and electricity. The negative effects that were carried out during this shock such as electricity shortages and the high prices increase the concern for ensuring energy system by defining, identifying and measuring other threats that can affect its performance.

However, although there is an extensive literature regarding security of energy supply, and after researching and analyzing various textbooks, papers and journal articles, it is apparent that there is no prior study that undertakes energy security for the electricity industry through considering the industry's value chain. This can be considered the core problem which this study located and will present. We support our argument with what some scholars [53] have considered in their research that there is a need for "developing better ways to summarize and visualize multiple energy security dimensions and attributes, including tabular, statistical, and graphical methods." Based on these situations, our research objective is to define and develop a proper manner for evaluating energy security in the electricity industry through taking into account ten different Latin American countries, and through studying the performance indicators for each system, which affects continuity of electricity supply through the whole value chain.

This research paper is organized in six sections containing the support of different sources. The first section contains the introduction which includes concepts, the objective, and problem statement. This section includes basic concepts in order to understand some of the characteristics of the electricity industry. The second section reviews the pertinent literature and theory regarding energy security. The third section encompasses the approach utilized for assessing security of electricity supply in ten selected Latin American countries. The fourth section exposes the obtained results; while in the fifth one are discussed the potential policy implications. Finally, the conclusions are given in the sixth section. The main contribution of this research document is to establish a manner for assessing security of electricity supply through considering the electricity industry's value chain and the core indicators which influence negatively the continuity of electricity supply.

2. Review of existing literature review

Some academics [27] have defined energy supply security as "ensure meeting ex ante demand for energy services at affordable prices." While on the other hand, regarding energy commodities some research institutions [48] have defined security of electricity supply as "the ability of the electrical power to provide electricity to end-users with a specified level of continuity and quality in a sustainable manner, relating to the existing standards and contractual agreements at the points of delivery." In both cases as well as to other twenty-seven different studies, regarding the development of concepts and measurements of energy security, the main concern is the availability and continuity of supply of primary energy resources as well as energy commodities such as fuels, heat and electricity.

Also, there were other definitions regarding energy insecurity [4; 7; 8; 21; 54; 57]. However, the most popular [25] is the one that set "energy insecurity stems from the welfare impact of either the physical unavailability of energy, or prices that are not competitive or overly volatile." Furthermore, it is a state that happens when in a specific energy system it is not possible to overcome negative situations affecting the proper delivery of energetic commodities or services to the final customers [6; 15]. The second study [15] in its definition took into consideration the factors influencing insecurity of energy supply such as the physical availability and the price component; while the second research, which is most approachable, is about searching for the factors that are belonging to a specific energy system and which are the main reasons for disruptions in delivering energetic commodities to the end users.

We agree that energy security is a multidisciplinary concept from which it emanates a set of policies, laws, regulations, and settled standards, as well as the actions that must be undertaken in order to supply without any kind of interruptions in the energetic commodities in different sub-sectors. Additionally, this concept in the electricity industry is the degree of reliability that is reached through guaranteeing continuity in the flows of power and electricity through the whole industry's value chain, that are designated to meet customers' demands, without interruptions and at affordable prices. Through the degree of certainty which is provided, policies, laws, regulations, standards as well as actions that contribute in achieving a higher level of certainty can be developed and undertaken. The continuity of supply on delivering the electricity service must be guaranteed by means of evaluating the efficiency of each system through reaching accepted standards.

Currently there is no consensus about which indicators have to be employed for measuring security of supply in the electricity industry. Two different groups of researchers [53; 55] have argued that it is essential to expand concepts and methodologies on assessing energy security in scopes that also are susceptible from threats and that have not been studied in detail previously. Some European institutions have proposed to employ standards and encompass the industry's value chain [47; 48]. Some institutions have argued in favor that measurements must be based on worldwide accepted international standards for assessing the degree of reliability of the electricity industry as a whole and for each individual system [44; 56].

There is an empirical methodology based on factors that can influence negatively the supplies of energy commodities [15]. The main purpose of the researcher was evaluating energy vulnerabilities and the author has taken into account the ECN/CIEP criteria regarding factors that can affect the energy supply chain. The investigation was supported with several indicators from previous researches which allow identifying the threats regarding energy supply. The result was a composite indicator called energy vulnerability index, which allowed measuring weaknesses related to energy demand/supply. In terms of energy security this indicator is important because it focused on identifying threats affecting supplies of energy commodities, which decrease the certainty about having enough energy resources for producing fuels or electricity.

This methodology also has encouraged other researchers [6], for adopting this approach and evaluates energy vulnerabilities in the electricity generation system in different geographical zones, which depends on gas imports for electricity production. All these studies provided a wide range of indicators clearly classified, which also granted developing criteria regarding the way to estimate insecurity of supply in the upstream market of the electricity industry. What may differ among them is the number of indicators or factors (energy vulnerabilities) regarded, because in the case of [15] five issues were accounted, while [6] took into account four matters. The second research of this type [6] was the more accurate in comparison with the other first one [15] because the scholar has employed indicators were clear and precise. Table 2.1 present the general employed methodology.

Table 2.1 Energy vulnerability index

Measurement	*Metric Formula*	*Source*
Energy Vulnerability Index	$EVI = [(\sum_{i=1}^{5} I^2_{ij})^{1/2}] \div I_{ij}$	[6; 15]

In addition, in terms of using relative indicators or scaled values the second research [6] has employed the maximums and minimums ranges values in order to perform better risks measurements. The scaled values can be considered as minimum standards that must be accomplished in order to obtain an acceptable performance. However, an extended analysis about situations and factors that might affect continuity of electricity supply in the other areas of the industry's value chain is still required. This model can be utilized in other areas that integrate the electricity industry value chain. In addition, it is necessary to account the infrastructure capacities factors as well as the demand factors as the threats, which are the basic technical indicators in assessing security of supply for the electricity generation system.

3. Approach and data

Our methodology consists of two core areas for measuring security of supply in the electricity industry of Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, and Peru. Furthermore, we have included Chile and Argentine. In one hand, we want to employ a set of simple, aggregated and relative indicators for developing an index to assess the electricity industry security of supply in those countries. On the other hand, we intend to use our Electricity Industry Security of Supply Index (EISSI) and through a linear regression analysis, our objective is to identify the main external factors that can influence the electricity industry performance in terms of security of supply. In addition, we are aimed to establish the trade-offs between efficiency of electrical infrastructure and security of electricity supply.

Most of the nations under study have deregulated their electricity industries during the 90s and due to these facts most of the statistical information is available since the year 2000. For the foregoing reasons, this research paper covers the time period from 2000 to 2011 in which most data is available for the selected indicators. Some academics [3] considered that at least 10 years is the needed time for analyzing the changes and effects in some areas under study. In addition, our data is unbalanced in view of the fact that some observations are not complete alongside with the studied time period and this limitation comes from the certainty that cross-regional research needs the mixture of various sources.

3.1 Assessing security of supply on the electricity industry through composite indicators

We develop an approach for assessing security of supply on the electricity industry. In other words, here we are focus on the industry's micro-environment. This sub-section is divided into two main areas. In the first part we have applied a set of simple, aggregated and relative indicators for assessing the performance of the electricity industry in terms of security of supply for Mexico, Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, Panama, Colombia, Ecuador, Peru, Chile and Argentine.

3.1.1 Simple, aggregated and relative indicators for assessing performance

Our simple, aggregated and relative indicators were based on available official statistical data regarding the achieved performance during the time period from 2000 to 2011, in the electricity industry from the under studied countries. The Appendix 1 the different sources consulted. The set of relative indicators was based on international and well recognized technical standards with the aim to support empirically our study. The studied measurements provided criteria about situations of insecurity in supplying the electricity through the industry's value chain. The Appendix 2 shows the way we have organized our model based on the selected.

Security of supply on the electricity industry encompassed availability of resources as well as the proper performance of electrical infrastructure for supplying the electricity service for end customers. Our proposal is formulated under the considerations regarding security of supply that were made before for researchers and institutions in their studies [10; 13; 22; 23; 24; 25; 28; 38; 41; 42; 50]. They were interested in finding measurements regarding insecurity of supply or threats affecting the delivery of energetic commodities. As it was seen in the figure above, most of the issues belong to the electricity industry's microenvironment and tend to affect its performance.

3.1.2 Composite indicators for assessing security of supply

The second part of our approach has assessed security of electricity supply in the electricity industry of the selected countries, through the use of a relative indicator: $\chi_{Tn} = [I_n - \min(I_n)] \div [\max(I_n) - \min(I_n)]$, (1). In each of the four investigated systems. Then, the achieved values for each relative indicator need to be subjected to: $0 \leq \chi_{ij} \leq 1$, (2). This constraint is employed due to the fact that some values from the simple and aggregated indicators were ranging below 0 or upper 1. Our aim is to do not affect the sensitivity that has to be reflected by the values of the Electricity Industry Security Supply Index (EISSI) in indicating security or susceptibility and for the previous reasons values between the referred ranges was captured. Results closer to 1 mean high risks, while values closer to 0 mean low risks.

Later on, it was possible to compute a set of composite indexes for assessing security of supply in each system of the electricity industry value chain. It is defined as one minus the root mean square of the average results of our relative indicators for each system (energy resources, power generation, electricity transmission and electricity distribution), which are divided into four[1]: $SVI_j = 1 - \sqrt{((\sum_{i=1}^{4} \chi^2_{ij}) \div 4)}$, (3). This mathematical model allows assessing threats affecting energy supplies on the different systems of the industry's value chain. It integrates the threats in order to develop our composite indexes. It is easy to understand and apply for analyzing the whole electricity industry value chain, and then through continue using the same methodology they can be combined with in order to obtain a general: $EISSI = \sqrt{((\sum_{i=1}^{4} \chi^2_{jk}) \div 4)}$, (4).

The aggregated indicators can be estimated by using a scaling technique where the minimum value is set to 0 and the maximum to 1. The value of 0 is assigned to the indicator with the least level of security of supply and value 1 was assigned to the indicator with high level of security of supply. Our preference in using this methodology was because it is more objective in comparison with other methodologies which were subjective and allocate less reasonable values or criteria to the model. To obtain our security index in the modeling part we have considered the monthly results from 2000 to 2011 of the main technical indicators of the electricity industry in the selected ten Latin American countries. Data was collected from the annual statistical reports issued by the electricity market operator, regulatory bodies as well as ministries of energy and mines as it can be seen in appendix two. Table 3.1 shows the different composite indicators for each system that integrates the electricity industry.

Table 3.1 Composite indicators for the different systems of the electricity industry

Description of the composite indicator	*Mathematical expression*
Security of Supply Index for the Resources System (ERS)	$RS = 1 - \sqrt{((\sum_{j=1}^{4} \chi R^2_{jk}) \div 4)}$, (5)
Security of Supply Index for the Electricity Generation System (EGS)	$EGS = 1 - \sqrt{((\sum_{j=1}^{4} \chi G^2_{jk}) \div 4)}$, (6)
Security of Supply Index for the Electricity Transmission System (ETS)	$ETS = 1 - \sqrt{((\sum_{j=1}^{4} \chi T^2_{jk}) \div 4)}$, (7)
Security of Supply Index for the Electricity Distribution System (EDS)	$EDS = 1 - \sqrt{((\sum_{j=1}^{4} \chi D^2_{jk}) \div 4)}$, (8)
Electricity Industry Security Supply Index (EISSI)	$EISSI = \sqrt{((\sum_{j=1}^{4} \chi^2_{jk}) \div 4)}$, (9)

Source: Elaborated by the authors with support from [6; 15]

As it can be seen in Table 3.1 the modification of the composite indicator employed by other researchers [6; 15] obeys to the fact that we are interested in developing an indicator that evaluates security levels instead of only assess vulnerability levels. It provides a more comprehensive understanding about threats affecting supplies of energy resources through study the whole industry's value chain. This model can be replied for the analysis of other sub-sectors which compose the energy industry as in the case of hydrocarbons as well as minerals once simple indicators and threats, and data can be available and identified. After combined all the indexes with the same model the general EISSI was obtained.

3.2 Assessing the Impact of external factors over security of supply on the electricity industry

The second part of our methodology intends to support empirically our study. We intend to use our Electricity Industry Security of Supply Index (EISSI) and through a linear regression analysis, our objective is to identify the main external factors that can influence the electricity industry performance in terms of security of supply. We consider that environmental, political, social as well as technological issues have influence over this type of industries. In addition, we are aimed to establish the trade-offs between efficiency of electrical infrastructure and security of electricity supply. Our panel date is unbalanced in view of the fact that some observations are not complete alongside with the studied time period and this limitation comes from the certainty that cross-regional research needs the mixture of various sources. We have developed our model with the support of previous studies[2] [19; 58], and thus the dependent variable is our EISSI[3], and the general equation is settled as follows:

$$EISSI_{jk} = \beta_0 + \beta_1 NP_{jk} + \beta_2 PS_{jk} + \beta_3 CR_{jk} + \beta_4 Z_{jk} + \varepsilon_{jk}, (10)$$

The external factors surrounding the electricity industry's macro environment have strong consequences on the security of supply due to the elements outside of the industry's range of control. Based on prior considerations [54] we have taken into account natural phenomena (PN), criminality (CR), political stability (PS), and a selected group of control variables (Z) for our selected countries. These variables are a clear reflection of the factors that can influence negatively or positively the performance the industry. In our general equation ε represents the error term, the subscript *j* specifies the country and *k* indicates the time period. The figure 3.4 shows our general empirical model scheme.

3.2.1 Natural phenomena (NP)

Natural phenomena (NP) can either be positive or negative [49; 52]. It integrates a set of climatological issues such as storms (ST), floods (FL), extreme temperature (ET), and droughts (DR). In this study it is assumed

[1] Gnansounou (2008) and Cabalu (2010).
[2] Jorgenson, A. K. 2006. "The Transnational Organization of Production and Environmental Degradation: A Cross-National Study of the Effects of Foreign Capital Penetration on Water Pollution Intensity, 1980–1995" *Social Science* 87: 711-730.
[3] The $EISSI = \sqrt{[(\sum_{j}^{4}=1\ \chi^2_{jk}) \div 4]}$, (9).

that natural phenomena have a negative impact over the continuity of electricity supply, because it can produce the collapse of basic infrastructure through the whole electricity industry value chain as well as the reduction of energetic feedstocks [18; 31]. Through this analysis it can be possible to prove if these climatological phenomena are associated with the frequency of occurrence of La Niña/El Niño–Southern Oscillation [29; 37]. La Niña is characterized by high temperatures as well as droughts, while El Niño is differentiated by carrying out low temperatures and rains. For this variable we have consulted the database of a regional organization [46].

3.2.2 Criminality (CR)

It is assumed that a country with a high victimization rate is susceptible of criminal activities against the public or private properties [5; 14]. We assumed victimization rate as criminal activities (organized practices of looting) against the public or private properties in the electricity industry activities such as piracy committed against vessels carrying fuels, robbery of components of transmission infrastructure, as well as theft of electricity at distribution level that is accomplished by end users [11; 40]. This variable allows identifying how social factors, as well as the victimization rate, relating to a given country can affect continuity of electricity supply. It is the percentage of people as well as institutions who say they were victims of criminal acts in the total survey population within a victimization survey. For this variable we have consulted the database of a regional organization [46].

3.2.3 Political stability (PS)

In the electricity industry for an investor it is important to have a minimum of certainty about the political stability of the country where he/she wants to invest, so that no extra-sectoral factors affect profitability [28; 30; 32]. This variable takes into account the risk that exists in a given geographical area or a country such as military coups, rebellions, terrorism, civil wars, where duties as well as commercial agreements, cannot be accomplished among others [41; 42; 54] It is the rating assigned in presence of risk, being 0 the value conferred in the absence of risk, while 0.7 is the highest given rate in the worst of the cases. For this variable we have consulted the report of an international organization [45] regarding risk classifications for partners on international trade transactions.

3.2.4 Control Variables (Z)

Our control variables are represented by dummy variables in order to control country's electricity industry specific effects. The variables Z1 and Z2 represent the negative effects of the most frequent natural phenomena matters over the electricity industry. Z1 regards to storms and Z2 to floods. The variables Z3 and Z4 consider the negative effects of socio-political situations in a given nation. Z3 concerns to political stability, while Z4 to criminality. In all the cases, the variables take a value of 1 if negative effects are considerable for a given nation and if they affect the performance of the electricity industry; while they take a value of 0 otherwise. For these variables we have consulted the database of a regional organization [46].

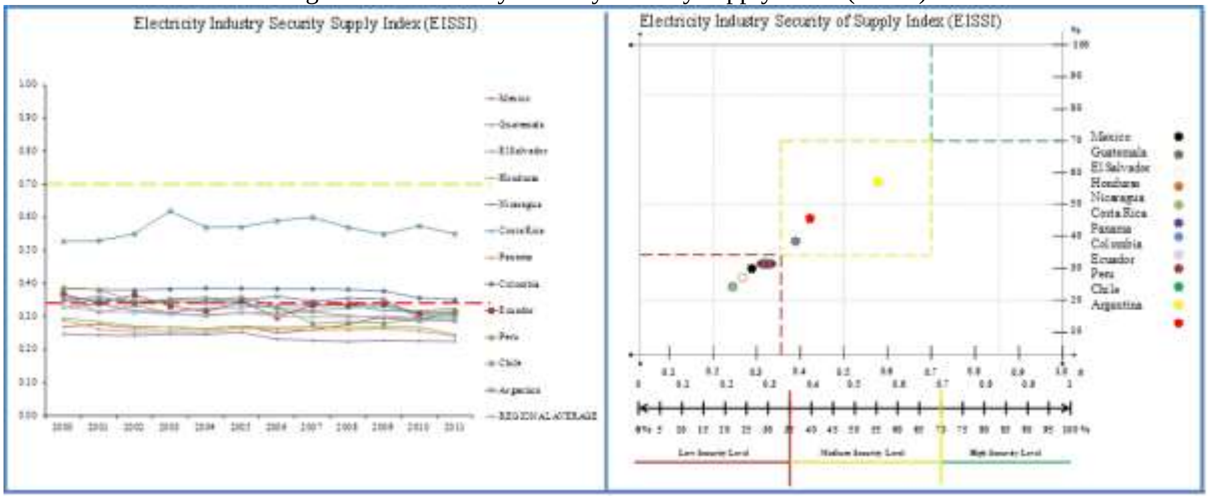
4. Results

4.1 Electricity industry security of supply index (EISSI)

The outcomes for most of the studied countries are ranging inside the limits of a low-high level of security of supply. Chile and Colombia are the nations ranging inside the limits of a medium level of security of supply. In general, the obtained values are ranging between 0.24 (24%) and 0.57 (57%) as it can be seen below in both scenes of Figure 4.7, regarding our EISSI. The causes of a low EISSI performance have been the poor performance in the different systems that compose the electricity industry in the studied nations. Therefore, Nicaragua is the state which has the lowest performance. Also, in this indicator it has been noticed that the tendency for most of the countries has been decreasing security of electricity supply with the exception of El Salvador, which has been the only state trying to improve its security of electricity supply.

With exception of Chile, in the Figure 4.1 it can be seen a concentration trend with respect to the safety levels of the electricity industry in the studied countries. It seems like security tends to be concentrated in the order of a 0.30 and 0.40 (30% and 40%). In order to match the obtained EISSI results with the downstream industry performance, where end users are located, we have studied for each electricity industry its system average interruption duration index (SAIDI). Comparing the outcomes of the EISSI with the SAIDI results for each nation, which are presented on the Appendix 3, we have found that, with exception of Colombia, the countries with lower values in their EISSI are the ones with the lower performance regarding the SAIDI. Most of the countries do not exceed accepted parameters regarding the SAIDI and also have similar outcomes regarding this last indicator which is correlated with the observed behavior with respect to the EISSI previously.

Figure 4.1 Electricity industry security supply index (EISSI)



Source: Elaborated by the authors

Finally, our EISSI has shown that the performance of the system is strictly attached to the infrastructure efficiency as well as the resource system outcomes. The low performance of most of the nation's studies in resource, generation as well as electricity generation systems have been the main cause for the low output of our EISSI. However, investments in infrastructure additions as well as timely maintenances are required in order to keep or increase the security and continuity of electricity supply. These situations are the main reasons affecting the security of supply of the electricity industry in the analyzed countries. As it was exposed before, electrical infrastructure has a nominal installed capacity which cannot be exceeded if there are not new additions of infrastructure or technological improvements. This constraint is due to the fact that productive facilities by nature are subjected to their nominal installed capacity and consecutively with their production frontier. As a matter of fact, the main cause of infrastructure overexertion is the increasing demand.

There exists an inherent connection between the different referred indicators in all the systems analyzed in this study. In the case of energy sources reserves and infrastructure capacities they are subjected to the restrictions that are found in the economic theory[4]. When a country decreases in a considerable amount its energy reserves it will start, in one hand, to swift its energy mix (technological infrastructure change) and importing energy sources from foreign trading countries. On the other hand, electricity generation facilities have a nominal installed capacity which cannot be exceeded if there are not new additions of infrastructure or technological upgrading. The lack of self-sufficiency in producing electricity domestically can generate negative outcomes in the balance of trade because imports dependency.

Infrastructure overexertion generates heat over itself, carrying out a low power factor, and it increases the losses on the different systems. In presence of losses and in order to meet demand requirement the downstream systems (distribution and transmission) pull-over the upstream systems (generation and resources). In this case the losses are compensated through demanding the employment of more power generation capacities as well as energy sources for electricity production. The utilization factor, the power factor and the losses tend to be higher in the electricity distribution system in comparison with the electricity transmission system. This phenomenon is due to the fact that the downstream industry where end users are placed is more dynamic or unstable in terms of electricity consumption. These situations have been noticed in most of the studied countries. Only Chile, Colombia and Peru are the group of countries with a more dynamic performance.

In the case of developing countries, the behavior of losses in both systems is dynamic due to the fact that this type of countries, as it is the case of most of the nations studied in the present research, are still accomplishing missionary activities. For example, most of these countries are still developing rural electrification activities as well as expanding other basic infrastructure in the electricity transmission system. The losses in the electricity distribution system are higher than the ones in the electricity transmission system. In addition, the rate of use for the electrical infrastructure in both systems tends to be superior for transformers than power lines. These situations are as an outcome of the own nature of the downstream industry in which electricity consumption behavior is more dynamic or unstable.

In our study we have found that security of supply depends on having enough energy resources to produce electricity as well as in infrastructure efficiency. These two situations are fundamental in order to satisfy demand consumption levels without exceeds nominal capacities that deteriorate equipments' lifetime. The electricity industry's performance has been affected when the countries were not adding new proven reserves and decreasing

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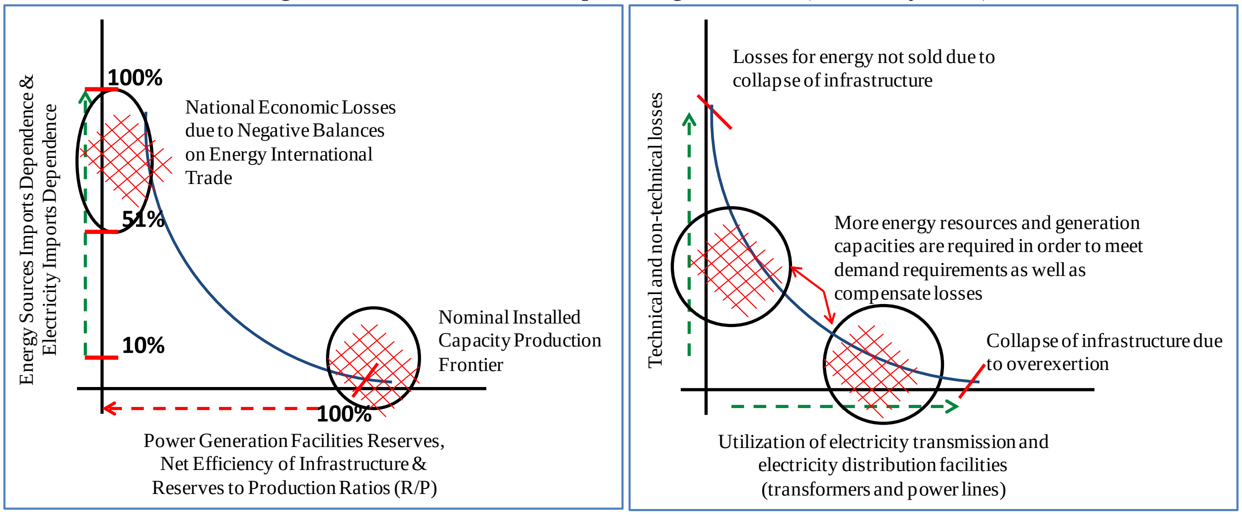
[4] Allen et al. 2010. "Managerial Economics: Theory, Applications, and Cases." New Your, United States: W. W. Norton & Company, Inc.; & Nicholson, S. 2010. "Theory and Application of Intermediate Microeconomics." Ohio, United States: South-Western Cengage Learning.

stocks as well as lacking the development of indigenous resources due to lack of facilities for transformation or they have not an access yet till the regions where energy sources were located. Also, there are trade-offs between the efficiency of the electrical infrastructure and external factors. We have seen that forces out of the industry's micro-environment tend to affect its performance either positive or negatively. Figure 4.2 shows the intrinsic relationships among indicators of the electricity transmission and electricity distribution systems.

Figure 4.2 Intrinsic relationships among indicators (in the 4 systems)



Source: Elaborated by the authors

4.2 The effects of external factors over security of supply on the electricity industry

We start by seeing the average outcomes for the EISSI as well as the main external factors that were considered. In one hand, we can see in Table A, inserted in Appendix 4, that security of supply on the Electricity Industry of the studied countries is in average 32.98%, which is a very poor result regarding their achieved performance after deregulation processes were implemented. On the other hand, we have that natural phenomena issues are dynamic in the Latin American region, since climatological occurrences have been reported per year. Most of the cases reported correspond to floods as consequence of heavy rains (storms). La Niña/El Niño–Southern Oscillation is a common characteristic of the Latin American countries studied. La Niña shows high temperatures as well as droughts every seven years, while El Niño is differentiated by carrying out low temperatures and rains along periods of seven years [29; 37].

The simple correlation analysis is presented in Table B, inserted in Appendix 5, and it reveals that criminality (CR) political stability (PS), storms (ST), and extreme temperature (ET) are the variables that can influence our EISSI. The correlation is both positive and negative. In one hand if the value of CR goes up, the value of our EISSI goes up too. On the other hand, if the value of ST, ET, and PS goes up, the value of EISSI tends to go down. These results might predict that CR, ST, ET, and PS would be statistically significant as predictor variables in the regression model. Furthermore, we have found that all of them are correlated. These results reflect that there are trade-offs between the efficiency of electrical infrastructure and natural disasters, socio-political-cultural, and technological issues [36; 43], because they can influence the performance of the electricity industry and security of supply. Regarding multicollinarity, it does not seem to be a problem in this study.

We have found heteroscedasticity while testing in our regression analysis. In order to solve this situation we have ran the regression model through employing robust standard errors. In the Table C, inserted in Appendix 6, are shown the parameter estimates for the regression equation. It was observed that ST, ET, and PS are the external factors that tend to decrease security of supply on the electricity industry in the studied countries. Since PS the most negative influential factor, we have that a climate of political instability can impair the ability of a region or country to attract new investments on its electricity industry as well as affect negatively the prices that can be offered to end consumers in presence of high levels of risks [28; 30; 32]. Furthermore, this indicator is also beaten by socio-cultural issues affecting a given nation. In the case of ET its negative influence over security of supply is less than PS.

Additionally, PS has the largest beta coefficient, (-1.3119 in absolute value), while our dummy variable regarding floods (Z3) has the smallest one (0.0035). In one hand, a one standard deviation increase in PS leads to a 1.3119 standard deviation decrease in predicting our EISSI, with the other variables held constant. On the other hand, a one standard deviation increase CR, in turn, leads to a 0.1971 standard deviation increase in predicted EISSI, with the other variables in the model held constant. Then, if a one-unit decrease in ST, ET and PS, they would yield a 0.0640, 0.0205 as well as a 0.6195 units increase in the predicted EISSI. In other words, they can either increase or decrease security of supply on the electricity industry. Finally, if a one-unit increase in CR it would yield a 0.1966 unit increase in the predicted EISSI.

Regarding our results, it was seen that criminality tends to influence positively security of supply. Although these activities attempt negatively against the physical infrastructure of the electricity industry as well the provision of the electricity service itself, their accomplishment also requires a prompt solution in order to do not interrupt the electricity service supply. We believe that it is as a consequence of the own nature of electricity service as 'public good'; however, negative effects of these types of situations can be translated on the prices provided for end customers [11; 40]. Finally, we have that power lines length influences positively security of supply since the growth of physical infrastructure is a factor that responds to demand requirements [12; 33; 59].

With a p-value of zero to four decimal places, we can set that our model is statistically significant. By dropping the constant term our R-square is higher (0.9210) and it makes the predictor coefficients stronger and more significant. Furthermore, if we decide to consider the constant term, our R-square result will still be acceptable (0.4255) since it remains in the minimum acceptable range. It is not expected a high value regarding this statistical measurement, because it is not probable that occurrence of external factors happen steadily during a single year [1]. We can say that our results regarding natural phenomena have fitted with the occurrence of La Niña/El Niño–Southern Oscillation [29; 37].

The Chatham Emergency Management Agency[5] has set about that "it is extremely unlikely that the probability of external factors' strikes will ever exceed 25-35% at the decision point required to make a timely mitigation decisions." However, since there is a possibility that they can occur, it cannot be ignored their effects over security of supply on the electricity industry as well as the possible policy implications in order to mitigate the potential negative effects.

5. Policy implications

Reports on electricity industry performance, especially on the downstream industry (electricity transmission and electricity distribution), should include information regarding power quality and frequency. These indicators allow identifying when infrastructure can collapse because of overexertion of transformers as well as conductors. The infrastructure overload can be as a consequence of increasing demand and it can carry out outages on supplying the electricity service. This situation can generate that electricity industry cannot meet demand requirements and it requires further investments on technological upgrading as well as building new infrastructures. If demand consumption levels over exceeds nominal capacity the continuity of supply can be affected. Information regarding ampacity must be public since this indicator is base on international standards such as IEC-60038 2002-07 regarding Standard Voltages, and IEC-60059 2000-03-21 regarding Standard Current Ratings.

Monitoring the indicators regarding capacities for electricity generation, electricity transmission as well as electricity distribution will contribute to develop and adopt prompt measures for strengthening continuity of electricity supply to end users. Regulatory bodies can control levels of used infrastructure against investments and new infrastructure development. Also, mechanisms to provide economic incentives in order to stimulate new infrastructure development as well as accomplish operation and maintenance activities on time can be proposed. Infrastructure aging factor also should be applied on the downstream industry systems in order to control and reduce levels of technical losses due to still stay operating with ancient equipments. Management of losses is required in order to prevent the use of extra capacities and resources along the industry's value chain.

Policymakers need to address new ways to stimulate private sector investments in R&D in the different systems that compose the electricity industry. It is because of the low performance as it has been noticed; it depends in the case of the resources system on the need of adding new proven reserves or shift to renewable energy resources. However, if in a given nation it is common that natural phenomena issues affect negatively security of supply, because its energy mix for producing electricity is mostly based on unstable renewable energy resources such as hydro or biomasses, policy makers should consider to accomplish the adoption of coal, nuclear or integrated gasification combined cycle technologies equipped with pollution abatement equipment.

In the case of electricity generation, electricity transmission and electricity distribution, it depends on upgrading the infrastructure and operates under quality standards; and in the case of energy imports security can be improved and risks may be minimized through diversifying suppliers.

6. Conclusion

In this paper we have considered a different energy security area, which has not been covered yet. The employed approach helped us to assess energy security in the electricity industry's value chain through considering the main risks that can affect infrastructure performance based on available data. This research was accomplished through considering the dimensions, attributes, and available statistical data as well as employ graphical information in clarifying our results. Based on our results we can set that there are trades-offs between the efficiency of electrical

[5] http://www.chathamemergency.org/evacuation-information/evacuation-timeline.php

infrastructure, security of supply, and external factors. Through our approaches we have shown that security of supply on the electricity industry depends on the physical infrastructure efficiency and the industry's performance also can be influenced either positive or negative by external factors belonging to the macro-environment, being storms, extreme temperature, and political stability the most negative influential issues, while criminality is the most positive influencing security of supply.

The EISSI model can be applied in the value chain of other business areas such as the case of hydrocarbons as well as minerals in the energy industry. The success of this model has been in defining clearly the threats affecting security and in defining well their importance with the available literature and data. All of this is possible since the fact that the root mean square of the average results of our relative indicators for each system (energy resources, power generation, electricity transmission and electricity distribution), which can be divided into *n* number of indicators. For any index model most of the risks are required to be identified on the physical infrastructure performance. In addition, an econometric assessment is vital in order to identify external factors from the industry's macro-environment that can affect security of supply of energy commodities.

By failing to comply with standards in certain activities of a system, the risk of failures increases. Later on, it will increase the possibility of interruptions in supplying the electricity service to end consumers. Otherwise when operating under compliance standards, the risk of failure in the service delivery tend to diminish considerably. The obtained results have shown that the performance of the electricity industry is attached to the infrastructure efficiency. Productive facilities by nature are subjected to their nominal installed capacity and consecutively to their production frontier. For the foregoing reasons, further investments in infrastructure additions as well as timely maintenances are required in order to keep or increase the security and continuity of electricity supply.

A stable, efficient and competitive national electricity industry contributes in increasing the economic growth and the population well-being. To accomplish these objectives, it is required that regulatory bodies in charge of supervising the quality of the electricity service adopt or develop more accurate controlling mechanism. Additionally, it is required to improve technical reports regarding the industry's operations in all the systems. These activities will contribute in safeguarding the integrity of the industry and protecting the interests of the customers. Well designed and standardized reports which include information regarding these indicators can add value to the industry's performance since they can be interesting for potential foreign investors which are trying to indentify not only countries that provide easiness in order to open new business that support productive activities without disruptions on supplying the electricity service.

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References

[1] Alcántara-Ayala, I. 2002. "Geomorphology, natural hazards, vulnerability and prevention of natural disasters in developing countries." *Geomorphology* 47: 107-124.

[2] Asif, M., and T. Muneer. 2005. "Energy supply, its demand and security issues for developed and emerging economies." *Renewable and Sustainable Energy Reviews* 11: 1388-1413.

[3] Baca, G. 2004. Project Evaluation. Mexico DF: McGraw-Hill.

[4] Bahgat, G. 2006. "Europe energy security: challenges and opportunities." *Intl. Affairs Journal* 82: 961.

[5] Balkin, S. 1979. "Victimization Rates, Safety and Fear of Crime." *Social Problems* 26: 343-358.

[6] Cabalu, H. 2010. "Indicators of security of natural gas supply in Asia." *Energy Policy* 38: 218-225.

[7] Chester, L. 2010. "Conceptualizing energy security and making explicit its polysemic nature." *Energy Policy* 38: 887.

[8] Costantini et al. 2007. "Security of energy supply: Comparing scenarios from a European perspective." *Energy Policy* 35: 210-226.

[9] Council of European Energy Regulators (CEER). 2011. "5th CEER Benchmarking Report on the Quality of Electricity Supply 2011." Brussels, Belgium: CEER.

[10] Davidson et al. 2002. "Technical loss computation and economic dispatch model for T&D systems in a deregulated ESI." *Power Engineering Journal* April: 55-60.

[11] Dick, A. J. 1995. "Theft of electricity-how UK electricity companies detect and deter." *European Convention on Security and Detection* 408: 90-95.

[12] Farrell et al.2009. "Energy Infrastructure and Security." *Ann. Rev. of Env. Res.* 29: 421-469.

[13] García et al. 2011. "Manual de Estadísticas Energéticas de la Organización Latinoamericana de Energía (OLADE) [Statistics Manual of the Latin American Organization of Energy]." Quito, Ecuador: OLADE

[14] Garofalo, J. 1979. “Victimization and the Fear of Crime.” *Research in Crime and Delinquency* 16: 80.
[15] Gnansounou, E.J. 2008. “Assessing the energy vulnerability: case of industrialized countries.” *Energy Policy* 36: 3734-3744.
[16] Ghosh, S. 2012. “Loss Reduction and Efficiency Improvement: A Critical Appraisal of Power Distribution Sector in India.” *International Journal of Modern Engineering Research (IJMER)* 2: 3292-3297.
[17] Graus, W.., and E. Worrell. 2007. “Effects of SO2 and NOX control on energy-efficiency power generation” *Energy Policy* 35: 3898.
[18] Guikema et al. 2010. “Prestorm Estimation of Hurricane Damage to Electric Power Distribution Systems.” *Risk Analysis* 30: 1744.
[19] Hattori, T. and M. Tsutsui. 2004. Economic Impact of Regulatory Reforms in the Electricity Supply Industry: A panel Data Analysis for OECD Countries. *Energy Policy* 32: 823-832.
[20] Helm, D. 2002. “Energy policy: security of supply, sustainability and competition.” *Energy Policy* 30: 173.
[21] Hughes, L. 2009. “The four ‘R’s of energy security.” *Energy Policy* 37: 2459-2461.
[22] Institute of Electrical and Electronics Engineers (IEEE). 2002. “Overhead Distribution Systems Reliability.” IEEE PTMV-1, 02-09-12.
[23] International Atomic Energy Agency (IAEA). 2005. “Energy Indicators for Sustainable Development: Guidelines and Methodologies.” Austria: IEA.
[24] International Electrotechnical Commission (IEC). 2000, 2002. “IEC Standards.” Geneva, Switzerland: IEC.
[25] International Energy Agency - The Organization for Economic Co-operation and Development (IEA-OECD). 2007. “Energy Security and Climate Policy.” Paris, France: IEA-OECD.
[26] Jamasb, T., D. Newbery, and M. Pollitt. 2004. “Core Indicators for Determinants and Performance of Electricity Sector in Developing Countries." July. Cambridge Working Papers in Economics No. 0438. Cambridge, UK: University of Cambridge.
[27] Jansen et al. 2004. “Designing indicators of long-term energy supply security.” The Netherlands: ECN, ECN-C-04-007: 1-35.
[28] Kruyt et al. 2009. “Indicators for energy security.” *Energy Policy* 37: 2166-2181.
[29] Landsea et al. 1996. “Downward trends in the frequency of intense Atlantic hurricanes during the past five decades.” *Geophysical Research Letters* 23: 1697-1700.
[30] Lefèvre, N. 2010. “Measuring energy security implications of fossil fuel resource concentration. *EnergyPolicy* 38: 1635-1644.
[31] Liu, Y. and C. Singh. 2010. “Evaluation of hurricane impact on composite power system reliability considering common-cause failures.” *International Journal System Assurance Engineering Management* 1: 135-145
[32] Löschel et al. 2010. “Indicators of energy security in industrialized countries.” *Energy Policy* 38: 1655.
[33] Moteff, J. 2011. “Critical Infrastructures: Background, Policy, and Implementation.” Congressional Research Report for Congress, Service 7-5700, RL30153, Washington, DC, United States: Congressional Research Service.
[34] Mukherjee, S. 2002. “Modern Economic Theory.” New Delhi, India: New Age International Publishers.
[35] Nooij et al. 2007. “The value of supply security: The costs of power interruptions: Economic input for damage reduction and investment in networks.” *Energy Economics* 29: 277-295.
[36] Pelling, M. and K. Dill. 2006. “Natural Disasters as Catalysts of Political Action.” ISP/NSC Briefing Paper 06/01, London, England: Chatham House.
[37] Pielke, R. and C.N. Landsea. 1999. “La Niña, El Niño, and the Atlantic Hurricane Damages in the United States.” *American Meteorological Society* 1: 227-233.
[38] Scheepers et al. 2006. “EU Standards for Energy Security.” The Hague, The Netherlands: Energy Research Centre of the Netherlands.
[39] Schwenen, S. 2011. “Security of Supply in Electricity Markets.” Doctoral Thesis, PhD Series 33-2011. Department of Economics and Management, Copenhagen Business School.
[40] Smith, T.B. 2004. “Electricity theft: a comparative analysis.” *Energy Policy* 32: 2067-2076.
[41] Sovacool, B.K. 2011a. “The Routledge Handbook of Energy Security.” New York: Routledge.
[42] Sovacool, B.K., and I. Mukherjee. 2011b. “Conceptualizing and measuring energy security: A synthesized approach.” *Energy Policy* 36: 5343-5355.
[43] Sönmez, S. 1998. “Tourism, Terrorism, and Political Instability.” *Annals of Tourism Research* 25: 416-456.
[44] The Organization for Economic Co-operation and Development (OECD). 2008. “ Handbook on Constructing Composite Indicators: Methodology and User Guide.” Paris, France: OECD Publishing.
[45] The Organization for Economic Co-operation and Development (OECD). 2012. “Country Risk Classifications of the Participants to the Arrangement on Officially Supported Export Credits.”[46] The United Nations Economic Commission for Latin America and the Caribbean (ECLAC). 2000-2011. “Central America Electricity Sub-Sector Stats [Estadísticas del Sector Eléctrico en Centro America].” Available at: http://websie.eclac.cl.

[47] The Regional Centre for Energy Policy Research (REKK). 2009. "Measures and indicators of regional electricity and gas supply security in Central and South-East Europe." Hungary: REKK 1: 1-48.
[48] The Union of the Electricity Industry (EURELECTRIC). 2006. "Security of Electricity Supply - Roles, responsibilities and experiences within the EU." Brussels, Belgium: EURELECTRIC.
[49] The United Nations (UN). 1985."Un Esquema para la Elaboración de Estadística del Medio Ambiente [Statistical Series: A Framework to the Preparation of Environmental Statistics]." New York, United States: Dept. of Econ. and Soc. Intl. Affairs, UN.
[50] United States Agency for International Development at India (USAID-India). 2010. "The Smart Grid Vision For India's Power Sector." India: PA Consulting Group.
[51] Usher, A. 1988. "A History of Mechanical Inventions." Cambridge, Massachusetts, USA: Harvard University Press.
[52] Vergara et al. 2007. "The Potential Consequences of Rapid Glacier Retreat in the Northern Andes." Working Paper No. 32. Washington, USA: LCR Sustainable Development, World Bank.
[53] von Hippel et al. 2011. "Introduction to the Asian Energy Security project: Project organization and methodologies." *Energy Policy*39: 6712-6718.
[54] Weisser, H. 2007. "The security of gas supply - a critical issue for Europe." *Energy Policy* 34: 01-05.
[55] Winzer, C. 2012. "Conceptualizing energy security." *Energy Policy* 46: 36-48.
[56] World Bank. 2000. "World Development Indicators 2000" Washington, United States: World Bank.
[57] Wright, P. 2005. "Liberalization and the security of gas supply in the UK." *Energy Policy* 33: 2272-2290.
[58] R. York et al. 2003. "STIRPAT, IPAT and ImPACT: analytic tools for unpacking the driving forces of environmental impacts." *Ecological Economics* 46:351-365.
[59] Zerriffi, Hisham, Hadi Dowlatabadi, and Alex Farrell. 2007. "Incorporating stress in electric power systems reliability models." *Energy Policy* 35: 61-75.

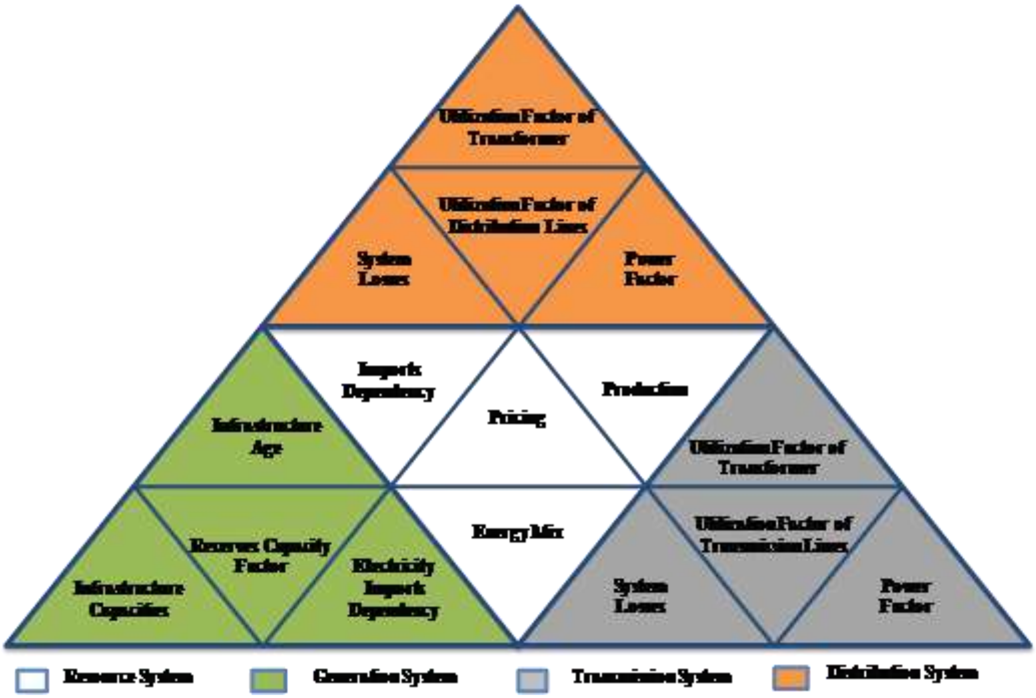
Appendix 1

- Data sources

Country	*Ministry Related with Energy Issues*	*Electricity Service Regulatory Body*	*System or Market Operator*
México	Secretaría de Energía http://www.sener.gob.mx/	Comisión Reguladora de Energía http://www.cre.gob.mx/	Comisión Federal de Electricidad http://www.cfe.gob.mx/
Guatemala	Ministerio de Energía y Minas http://www.mem.gob.gt/	Comisión Nacional de Energía Eléctrica http://www.cnee.gob.gt/	Administrador del Mercado Mayorista http://amm.org.gt
El Salvador	Ministerio de Economía http://www.minec.gob.sv/	Superintendencia General de Electricidad y Telecomunicaciones http://www.siget.gob.sv/	Unidad de Transacciones S.A. de C.V. http://www.ut.com.sv/
Honduras	Secretaría de Recursos Naturales y Ambiente http://www.serna.gob.hn/	Comisión Nacional de Energía http://www.cne.gob.hn/	Empresa Nacional de Energía Eléctrica http://www.enee.hn/
Nicaragua	Ministerio de Energía y Minas http:// www.mem.gob.ni/	Instituto Nicaragüense de Energía http://www.ine.gob.ni/	Centro Nacional de Despacho de Carga http://www.cndc.org.ni/
Costa Rica	Ministerio Ambiente, Energía y Telecomunicaciones http://www.minae.go.cr/	Autoridad Reguladora de los Servicios Públicos http://www.aresep.go.cr	Instituto Costarricense de Electricidad http://www.grupoice.com/wps/portal/
Panamá	Secretaría Nacional de Energía http://www.energia.gob.pa/	Autoridad Nacional de los Servicios Públicos http://www.asep.gob.pa/	Empresa de Transmisión Eléctrica – Centro Nacional de Despacho http://www.etesa.com.pa/ http://www.cnd.com.pa/
Colombia	Ministerio de Minas y Energía http://www.minminas.gov.co/	Comisión de Regulación de Energía y Gas http://www.creg.gov.co/html/i_portals/index.php	XM http://www.xm.com.co/Pages/Home.aspx
Ecuador	Ministerio de Electricidad y Energía Renovable http://www.energia.gob.ec/	Consejo Nacional de Electricidad http://www.conelec.gob.ec/	Centro Nacional de Control de Energía http://www.cenace.org.ec/
Perú	Ministerio de Energía y Minas http://www.minem.gob.pe/	Organismo Supervisor de la Inversión en Energía y Minería http:// www.osinerg.gob.pe/	Comité de Organización Económica del Sistema Interconectado Nacional http://www.coes.org.pe/wcoes/inicio.aspx
Chile	Ministerio de Energía http://www.minenergia.cl/	Comisión Nacional de Energía http://www.cne.cl/	Centro de Despacho Económico de Carga Sistema Interconectado Central https://www.cdec-sic.cl/index_en.php
Argentina	Secretaria de Energía http://energia3.mecon.gov.ar/home/	Ente Nacional Regulador de la Electricidad http://www.enre.gov.ar/	http://portalweb.cammesa.com/default.aspx
		Other Data Sources Consulted Regarding Economic and Energy Issues	
Regional	Comisión Económica para América Latina y el Caribe http:// www.eclac.org/	Asociación Latinoamericana de Integración http://www.aladi.org/	Sistema de Interconexión Eléctrica de los Países de América Central http://www.eprsiepac.com/

Appendix 2

➢ Simple, aggregated and relative indicators for assessing performance



Simple, Aggregated and Relative Indicators							
Energy Resources System				*Electricity Generation System*			
RPR	RPR = Res. ÷ Annual Prod.	**$10 \leq \chi_{R1} \leq +\infty$**	EIA (2007)	EI	EI = ei ÷ pi	**$0\% \leq \chi_{G1} \leq 10\%$**	Sovaccol and Mukherjee (2011)
ESI_{price}	ESI_p = *Pij*(Cf÷*TES)	**$0 \leq \chi_{R2} \leq 200$**	EIA (2007); Lefèvre (2010)	RCF	RCF = MPD ÷ NIC	**$5\% \leq \chi_{G2} \leq 20\%$**	Scheepers et al. (2006)
ID	EI = ei ÷ pi	**$0\% \leq \chi_{R3} \leq 10\%$**	Sovaccol and Mukherjee (2011)	EIC	EIC = AUF÷NIC	**$75\% \leq \chi_{G3} \leq 100\%$**	Scheepers et al. (2006)
EM	$EM = \sum_i S_{if}^{\ 2}$	**$0 \leq \chi_{R4} \leq 3333$**	Lefèvre (2010)	IAF	IAF = AAPP÷AEL PP	**$1\% \leq \chi_{G4} \leq 80\%$**	Ghosh (2010); Sovaccol and Mukherjee (2011)
Electricity Transmission System				*Electricity Distribution System*			
Uft	Uft = MC ÷ NC	**$40\% \leq \chi_{T1} \leq 90\%$**	IEC (2000, 2002); IEEE (2002)	Uft	Uft = MC ÷ NC	**$40\% \leq \chi_{D1} \leq 90\%$**	IEC (2000, 2002); IEEE (2002)
Ufpl	Ufpl = MC ÷ NC	**$40\% \leq \chi_{T2} \leq 90\%$**	IEEE (2002) IEC (2002, 2004a, 2004b, 2006)	Ufpl	Ufpl = MC ÷ NC	**$40\% \leq \chi_{D2} \leq 90\%$**	IEEE (2002) IEC (2002, 2004a, 2004b, 2006)
Lt	Lt = [Et –Ed-Ex]÷100	**$1\% \leq \chi_{T3} \leq 7\%$**	Innocent et al. (2002); USAID-India. (2010); Ghosh (2012)	Lt	Lt = [Et –Ed-Ex]÷100	**$1\% \leq \chi_{D3} \leq 10\%$**	Innocent et al. (2002); USAID-India. (2010); Ghosh (2012)
Pf	Pf = P ÷ |S| = cos (Φ)	**$0.9 \leq \chi_{T4} \leq 1.0$**	Innocent et al. (2002); USAID-India. (2010); Ghosh (2012)	Pf	Pf = P ÷ |S| = cos (Φ)	**$0.8 \leq \chi_{D4} \leq 1.0$**	Innocent et al. (2002); USAID-India. (2010); Ghosh (2012)

- Relative Indicators: $\chi_{Tn} = [In - min(In)] \div [max(In) - min(In)]$. Subjected to: $0 \leq \chi_{jk} \leq 1$.

List of acronyms of the simple, aggregated and relative indicators:

Energy Resource System	*Electricity Generation System*
RPR: Reserves-to-produce ratio	**EI:** Electricity imports level
ESIprice: Energy security index price	**RCF:** Reserves capacity factor
ID: Imports dependency	**EIC:** Effective installed capacities
EM: Energy Mix	**IAF:** Infrastructure age factor
Electricity Transmission System	***Electricity Distribution System***
Uft: Utilization factor transformer	**Uft:** Utilization factor transformer
Ufpl: Utilization factor power lines	**Ufpl:** Utilization factor power lines
Lt: Losses factor	**Lt:** Losses factor
Pf: Power factor	**Pf:** Power factor

Appendix 3

➢ System average interruption duration index (SAIDI - in minutes per event)

System Average Interruption Duration Index (SAIDI - in minutes per event): Electricity Industry of 10 Selected Latin American Countries												
Year/Country	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**
Mexico	177.6	160.97	309	141.73	113.56	179.88	108.26	154.27	156.02	97.83	136.1	130.32
Guatemala	15.05	14.25	14.55	13.49	10.03	10.23	7.62	4.21	6.92	7.73	8.03	8.43
El Salvador	15.62	14.79	15.1	14.01	10.41	10.62	7.91	4.37	7.18	8.02	8.33	8.75
Honduras	148.48	134.58	258.31	118.48	94.94	150.37	90.50	128.96	130.44	81.79	113.78	198.95
Nicaragua	16.05	14.04	13.04	13.44	12.01	14.71	16.68	14.93	29.05	8.96	7.99	10.54
Costa Rica	21.2	20.77	17.88	18.31	16.45	16.69	16.85	15.55	15.28	14.9	14.76	15.05
Panama	30.1	33.11	35.11	24.08	20.06	10.03	10.03	9.03	9.03	8.03	10.03	10.03
Colombia	8.05	5.04	6.82	3.6	4.41	3.34	5.15	4.06	4.24	4.21	4.63	5.1
Ecuador	7.99	7.78	7.56	7.34	7.12	6.92	6.71	3.42	4.74	7.78	7.86	7.93
Peru	12.04	10.03	9.53	11.04	10.03	11.49	10.23	11.44	13.54	11.04	13.34	12.94
Chile	N/A	N/A	N/A	N/A	N/A	N/A	2.16	1.98	2.36	9.79	2.74	2.39
Argentina	7.40	6.20	4.60	4.70	4.30	5.10	5.00	6.60	8.30	8.80	10.60	11.00

Source: National regulatory bodies from the 12 countries under study (information available on the Appendix 1)

Appendix 4

➢ Table A. Descriptive statistics

Variables	*Mean*	*Standard Deviation*	*Min.*	*Max.*
Dependent variable				
Electricity Industry Security of Supply Index (EISSI)	0.3298	0.0837	0.2239	0.6191
Independent variables				
Storms (ST)	0.0923	0.1534	0	0.7143
Floods (FL)	0.2034	0.1599	0	0.7143
Extreme Temperature (ET)	0.0278	0.0592	0	0.2857
Droughts (DR)	0.0188	0.0485	0	0.1429
Political Stability (PS)	0.4755	0.1772	0.2	0.7
Criminality (CR)	0.3568	0.0839	0.12	0.73
Z1	0.0417	0.2005	0	1
Z2	0.0417	0.2005	0	1
Z3	0.5069	0.5017	0	1
Z4	0.2083	0.4075	0	1

Number of observations employed: 144

Appendix 5

➢ Table B. Pairwise correlation coefficients of the EISSI

	EISSI	*ST*	*FL*	*ET*	*DR*	*PS*	*CR*	*Z1*	*Z2*	*Z3*	*Z4*
EISSI	1.0000										
ST	-0.0426	1.0000									
FL	0.0492	0.2071	1.0000								
ET	-0.0590	0.0773	0.0473	1.0000							
DR	0.0447	0.0907	-0.1113	0.0152	1.0000						
PS	-0.4297	0.1544	0.0134	0.1243	0.0546	1.0000					
CR	0.1394	0.1200	0.1761	0.0321	0.0026	0.1927	1.0000				
Z1	0.0203	0.7184	0.1077	-0.0140	0.0241	0.2244	0.1493	1.0000			
Z2	0.0404	0.0041	0.5128	-0.0140	-0.0813	-0.0805	0.0537	-0.0435	1.0000		
Z3	-0.1925	0.1149	-0.0862	0.1280	0.0972	0.8913	0.2164	0.2056	-0.1419	1.0000	
Z4	0.0629	0.0579	0.1731	0.0483	-0.0484	0.1721	0.7005	0.0642	0.0642	0.1981	1.0000

Number of observations employed: 144

Appendix 6

➢ Table C. Regression results with robust standard errors for the analysis of the EISSI

Model	*Parameter Estimate*	*Standard Error*	*<T Statistic>*	*Beta*
Storms (ST)	-0.0640	0.0489	-1.31	-0.1172
Floods (FL)	0.0697	0.0386	1.80	0.1331
Extreme Temperature (ET)	-0.0205	0.0832	-0.25	-0.0145
Droughts (DR)	0.0769	0.1024	0.75	0.0446
Political Stability (PS)	-0.6195	0.0879	-0.704	-1.3119
Criminality (CR)	0.1966	0.0961	2.05	0.1971
Z1	0.0691	0.0304	2.27	0.1656
Z2	0.0014	0.0370	0.04	0.0035
Z3	0.1560	0.0246	6.35	0.9347
Z4	-0.0121	0.0187	-0.64	-0.0588

Number of observations employed: 144