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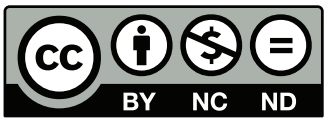

INTERNATIONAL TENDENCIES ON ENERGY SECURITY: A REVIEW ON NATIONAL ENERGY POLICIES IN THE ELECTRICAL SECTOR

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ABSTRACT

Energy security constitutes a priority within national energy policies. The international trend of energy transitions has fostered electrification of the energy systems, so it results imperative to study how the concept of energy security is implemented by means of power system strategies.

This article presents a review on seven different national security strategies focused in the power system, thus different approaches in the matter are contrasted and discussed. An outlook of the current situation in the selected nations is also presented, through the review of their power system structures and electricity generation data. Common paths among the national covered strategies are identifiable as a result of the study, including the deployment of renewable energies installations, efficiency improvement and, more geographically restricted, the shale revolution.

A frame able to qualify the strategies in a wide context would help policy makers to develop more country-specific strategies and to evaluate their effectiveness on procuring energy security.

Keywords: Energy Policy, Energy Security, Energy Transitions, Power System, Sustainability.

RESUMEN

La seguridad energética constituye una prioridad dentro de las políticas energéticas nacionales. Las transiciones energéticas como tendencia internacional han promovido la electrificación de los sistemas energéticos, por lo que resulta imprescindible estudiar cómo el concepto de seguridad energética se implementa a través de estrategias en el sector eléctrico.

Este artículo presenta una revisión de siete diferentes estrategias nacionales enfocadas al sistema eléctrico, para así poder contrastar y discutir distintos enfoques en la materia. Se presenta, además, una perspectiva de la situación actual de los países elegidos a través de la revisión de sus estructuras eléctricas y de sus datos de generación eléctrica. Se pueden identificar patrones comunes entre las estrategias estudiadas, los que incluyen el despliegue de instalaciones de energías renovables, el mejoramiento en la eficiencia y, de modo más restringido geográficamente, la shale revolution*.*

Un marco para calificar las estrategias en un contexto amplio ayudaría a los responsables políticos a desarrollar estrategias específicas para cada país, así como a evaluar su efectividad para procurar la seguridad energética.

***Palabras Clave*:** *Política Energética, Seguridad Energética, Sustentabilidad, Sector Eléctrico, Transiciones Energéticas.*

INTRODUCTION

A trend has been heading the international energy agenda during the last decade: the transition to sustainable energy systems. Nevertheless, there does not exist only one energy transition, but every country has its own path for transforming its energy system depending on its own circumstances. This fact takes governments to approach their transitions from different perspectives, and to issue and implement strategies that might diverge notably among them.

This series of energy transitions have taken the power system to occupy a central role for policy makers, since electrical systems, as the linking network among other public facilities, have become the center of modern infrastructures (Fischer, Hake, Kuckshinrichs, Schröder, & Venghaus, 2016). Moreover, the electrical system is crucial for the integration of renewable energies at a large scale, a key measure for fight against climate change.

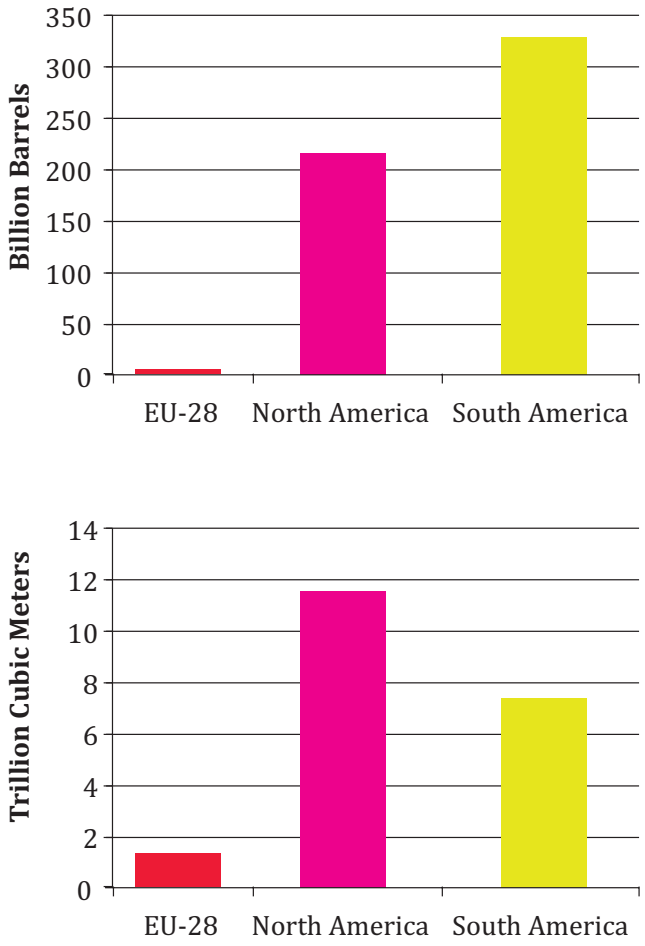
The power system, occupying such a prominent role in the energy system today, makes of assuring its energy security[1] a priority for governments. Procuring an appropriate, integrated and reliable network is, besides an energy policy objective, a part of a national economic strategy (Yusta, Correa, & Lacal-Arántegui, 2011).

The present article has the aim of, within the frame of global energy transitions, contrasting strategies of three different regions towards improving energy security in their power systems. The regions to be covered are Europe, North and South America. Through the analysis of strategies of countries located in those regions, general trends are to be identified and discussed.

ENERGY POLICY TRENDS IN ENERGY SYSTEMS

Different regions around the world tend to use indigenous resources to satisfy their energy needs. In the frame of the current international electrification trend, governments are shaping their energy systems with the prominence of the electrical system and, to the extent of possible, draw upon fuels within their borders for satisfying their energy needs.

Figure 1: Crude oil (top) and natural gas (bottom) proved reserves in the European Union & Eurasia, North and South America.



Source: Elaboration of authors with data from (U.S. Energy Information Administration, 2018a, 2018c)

1 Defined as "the uninterrupted availability of energy sources at an affordable price" (International Energy Agency, 2017).

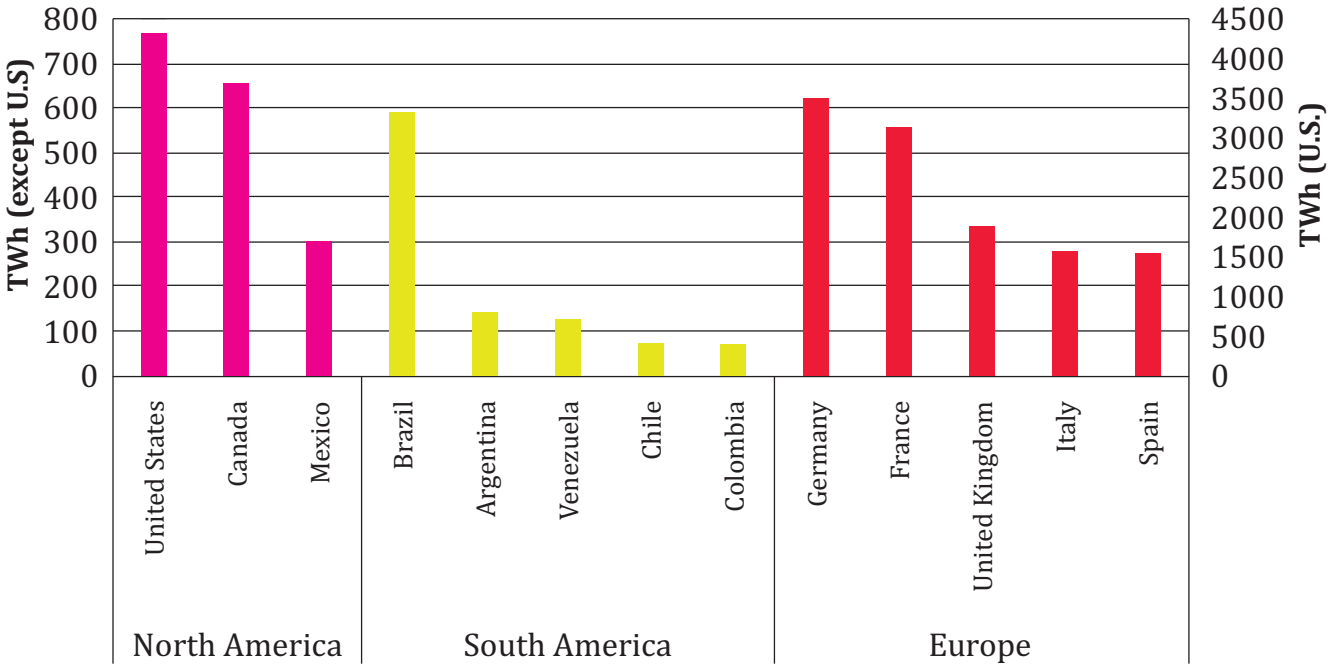
The European Union, one of the regions with less conventional resources in the world, as it can be observed in Figure 1, has decided to address this lack of sources through the promotion of renewable energies, diversification of both energy suppliers and technologies, efficiency measures and interconnections among the member states of the union (European Commission, 2014).

North and South America have very distinct approaches to those of Europe, since these regions possess some of the largest oil and gas reserves in the world, as well as a very high potential of renewable energies. North America, the top performer energy security region in the world (Wang & Zhou, 2017), has reserves enough to be self-sufficient energetically. Nevertheless, this region has been also promoting the deployment of clean energy technologies, particularly in the power system.

By its part, South America, due to its vast reserves of fossil fuels as well as its large use of hydropower, is not only an energy-secure region, but also a leader in environmental sustainability.

For the present article, the most relevant countries in terms of electricity production of the mentioned regions will be covered. Their electricity generation data is shown in Figure 2. The larger electricity producers of North America are the United States and Canada. Brazil is by far the largest generator of South America, followed by Argentina. By its part, Mexico, located in northern part of the continent but historically and culturally closest to the southern part of the continent -where it would occupy the second place as energy producer- has also been included for its analysis. Germany and France take the lead in Europe in the first and second place, respectively.

Figure 2: Total electricity generation in 2014.



Source: Elaboration of authors with data from (International Energy Agency, 2016)

United States

The United States has, among its energy objectives, the aim of becoming energy independent as its core mission for assuring its energy security (Congress of the United States of America, 2007). The strategy for achieving that independence consists of fuels, sources and routes diversification jointly with the boost of domestic resources exploitation (The White House, 2015).

The country reaches 447 GW of natural gas power plants, the largest fuel present in the power mix, which produced 34% of the 4,078 TWh generated in the country in 2016, followed by coal power plants, which sum 270 GW of installed power and contributed with 30% of the electricity production (U.S. Energy Information Administration, 2017b).

Towards 2040, it is expected that the energy intensity of the country continues decreasing as it has been doing since the last four decays (Institute for 21st Century Energy, 2016). This tendency will make that, through new efficiency standards and, in general, a less-energy-intense economy, the electricity demand in the country will continue growing, yet at a much slower rate (U.S. Energy Information Administration, 2017a).

Coal and natural gas will still remain the main sources of electricity generation in the U.S. in the mid-term, in spite of the efforts of the last federal administration and those of the federal states to promote renewable energies (Tsai & Gülen, 2017). Among renewable technologies, hydropower is to be overpassed by wind and solar power. Unlike other nations and because of its federal system, which provides strong capabilities to the states, are these ones those in charge of establishing their own targets on deployment of renewable energies, GHG emissions and other environmental concerns.

The current federal administration, through its executive order on "Promoting Energy Independence and Economic Growth" has derogated regulations considered unnecessarily restrictive and an obstacle for economic growth, all with the aim of ensuring geopolitical security of the U.S. (Trump, 2017). This order has the objective of promoting the exploration and production of local energy resources, including both conventional and renewable ones.

The U.S. is one of the current promoters and beneficiaries of the "shale gas revolution", which consists basically of technology development for the extraction of shale gas and its further implementation. This revolution has taken the U.S. to be the largest natural gas producer in the planet and the acceleration of its economy due to this energy boost (Arezki, Fetzer, & Pisch, 2017). Shale gas is a tool for the country to reduce its dependence on foreign energy sources and, by those means, improve its national energy security.

The U.S. is involved in a deep transformation, not only energetically but socially and politically. As a consequence, the energy trends that the country had experimented until the last administration, such as the promotion of renewable energies and regulation on GHG emissions, are currently under revision. The federal administration is today aimed to boost the use of local resources as the way to achieve energy independence and to improve the national energy security of the U.S., even if that view goes against the global trend of transforming energy systems to less-carbon-intense ones. It remains to be seen that if the competitively and leadership of the country do not result negatively affected in the long-term.

Canada

Canada, a mature post-industrial economy, has large natural endowments of oil, natural gas, coal and hydropower potential. With its current power system structure, Canada is energy secure (Best et al., 2010). This condition

is reached thanks to the vast resources the country possesses, its diversified energy mix, robust infrastructure, adequate market regulations supporting private investments and political stability (Langlois-Bertrand, 2010).

Due to the large extension of the country and propitious geological conditions, hydropower has a very strong presence in the Canada's energy mix with 77 GW of installed capacity, followed by natural gas, which accounts 21 GW (National Energy Board, 2016a). Thanks to this hydropower prominence, Canada is the second largest electricity producer from this source in the world; in 2015 hydropower supplied 59.3% of the 631.7 TWh of consumed electricity in the country (Statistics Canada, 2016).

There are several reasons for Canada to rely so heavily on hydropower, such as its flexibility, relative affordability, lack of CO_2 emissions and cost stability (National Energy Board, 2016a). By its part, the second major resource for the Canadian power system, natural gas, has the advantage of having low source prices, lower GHG emissions than other fossil fuel power plants as well as shorter construction times.

The total energy use of the country is expected to grow as well as the electricity use (North American Cooperation on Energy Information, 2015), a tendency extended to GHG emissions, while the energy intensity of the Canadian economy will follow a declining trend in the upcoming years (National Energy Board, 2016a). New installations in the country will be mainly natural gas-, wind- and hydropower-based technologies, while solar jointly with other renewable technologies will have a relatively minor participation increase in the energy mix; at the same time the system will suffer reductions of coal, nuclear and oil-fired power plants.

The Canadian Energy Strategy has focused its priorities on energy efficiency, energy access, climate change, a lower-carbon economy, technology and innovation (International Energy Agency, 2015). The Canadian Government, through the Energy Safety and Security Act (Parliament of Canada, 2015), has established a frame for assessing environment protection measures for oil and gas operations. National targets include reducing its GHG emissions by 30% compared to year 2005 by 2030 (Office of the Parliamentary Budget Officer, 2016), focusing this strategy on buildings and transport improvements.

Due to the federal administration of Canada, are the provinces and territories those in charge of primary overseen electric reliability (Natural Resources Canada, 2016), reason why there does not exist a national common target on renewable energies deployment, but are the provinces and territories themselves those who establish environmental objectives (International Renewable Energy Agency, 2015).

Because of its geographical location, the Canadian power system has interconnections only with its southern neighbor, to which it exported a net amount of 59.5 TWh in 2015 (National Energy Board, 2016b), exports that are highly dependent on weather conditions and electricity markets of the U.S. (National Energy Board, 2016a).

Summarizing, Canada has resources enough not only to energetically satisfy itself but also to export them. Besides the energy policies of the United States, the Canadian power system behavior in the upcoming years will be highly dependent on technology, particularly the proper integration of RE into the grid as well as sufficient storage. Currently, the country produces three quarters of its electricity from non-GHG-emitting sources and, due to its diversified, competitive secure and reliable energy supplies, Canada makes a contribution to global ES (International Energy Agency, 2015), an example of success in energy matters for the region and the whole continent.

Mexico

The Mexican energy sector is one of the most important industries in the country in terms of its contribution to the national social development and economy (Alpizar, Castro, Rodríguez, & Monroy, 2016). In 2013 Mexico faced a very significant change in its recent history: The Energy Reform. These series of amendments to the Constitution have been a breakthrough for the energy industry and all the related value chain, added to the fact that the energy sector has been considered a symbol of national sovereignty. The purpose of this new scope in the energy sector of Mexico is to improve energy access, with the objective of guaranteeing ES in the country and to boost the national economic development (*Gobierno de la República*, 2014).

The structure of the power system relies very heavily on fossil fuels, particularly natural gas in combined cycle power plants with 23.56 GW of installed power (*Comisión Federal de Electricidad*, 2017a), that in year 2016 produced 142.02 TWh, 54% of the electricity in Mexico (*Comisión Federal de Electricidad*, 2017b).

Towards 2040 and due to the exporting nature of its economy, Mexico is expected to be one of the fastest GDP expanding countries among the OECD members as well as one with the highest commercial energy consumption (U.S. Energy Information Administration, 2018b). Mexico is in the top five of the Americas' countries by both oil and natural gas reserves (Central Intelligence Agency, 2016a, 2016b), besides having a high potential of renewable energies, including solar, wind, biomass, hydropower and geothermal (Alemán-Nava et al., 2014). Due to the energy reform, there is expected to be a 1.4% to 3.6% increase in manufacturing output and a 0.2% to 0.6% increase of the gross domestic product (Alvarez & Valencia, 2016). All these factors are translated into an increase in the maximum power demand and electricity consumption (Mendoza-Vizcaino, Sumper, Sudria-Andreu, & Ramirez, 2016).

The electric power generation sector is the main one consuming natural gas and it is expected to account for 75% of consumption growth until 2027, a 57% of the national demand (Feijoo, Huppmann, Sakiyama, & Siddiqui, 2016). The Reform should, through competition introduction, allow new technology to expand gas basins exploration and to boost its national use in new power plants for injecting it into the market (Alpizar et al., 2016). In a 2029 scenario, the natural gas production in Mexico is expected to grow but the demand would do it at a faster rate, a difference compensated by imports, mostly from its northern neighbor (The National Energy Board Canada, *Secretaría de Energía de México*, & U.S. Energy Information Administration, 2015). The current north-to-south natural gas flow in North America will prevail unless Mexico decides to revert this pattern through self-sufficiency measures (Feijoo et al., 2016).

Mexico is a world climate change mitigation leader country with a Climate Change Law that enabled to establish an institutional framework to set goals and to foster plans and programs as

mechanisms for adapting the country to climate change (Grande-Acosta & Islas-Samperio, 2017). For 2030 the installed capacity of the country is expected to be 61% larger than the one installed today, being dominated by combined cycle power plants. By its part, in the produced electricity there will be a participation of 59% of conventional sources and 41% of clean energies (*Secretaría de Energía*, 2016b). The Energy Transition Law fixes a minimal participation –up to 50% by 2050- of clean energies in the total electricity generation (*Congreso General de los Estados Unidos Mexicanos*, 2015). Moreover, this law stipulates GHG emissions abatement and energy intensity depletion targets towards year 2050 (*Secretaría de Energía*, 2016a), summarized in Table 1.

Despite its high solar potential (Alemán-Nava et al., 2014), the planning of the government does not include an important scheme to explode it, since the participation of solar technologies, both photovoltaic and thermal, are expected to contribute only to a 6% of the total electricity production in a 2030 horizon (*Secretaría de Energía*, 2016b).

There exists also the need for a deeper integration in the electrical grid since the energy reform makes a clear statement to move Mexico's system toward north-neighboring systems (Ibarra-Yunez, 2015), supported by the fact that US electricity systems are mature and grids are rather deep and widespread (Ibarra-Yunez, 2015). Between Mexico and the United States exist 11 international electrical interconnections, while Mexico has two with Central America (*Secretaría de Energía*, 2016b).

The large energy consumption zones of Mexico, the northern region particularly (Rosas-Flores, 2017), are not connected to the centers of high RE potential (*Gobierno de la República*, 2014). Thus, it is imperative for the Mexican government to enhance national interconnections in the country, so an energy union could be achieved inside the borders, prioritizing inner demand coverage with local resources before importing energy.

The Energy Reform in Mexico represents a watershed in for the country in several ways, since a critical economy sector for the country has been modified deeply. The opening to private investors to participate in energy resources exploitation in favorable conditions (Merchand, 2015) should relief the Mexican economy and create new opportunities for both, companies and the people. Competition promotes improved performance in terms of greater electricity generation, generating capacity and improved labor productivity and capital utilization (Zhang, Parker, & Kirkpatrick, 2008), and all these, if managed appropriate, should improve the Mexico's ES.

Brazil

The Brazilian economy is, in terms of gross domestic product, the most important of South America (The World Bank, 2015). The country has, after Venezuela, the second largest oil and natural gas reserves in the region (Abdul-Hamid et al., 2016). Brazil is also by far the largest electricity producer of South America, with 50.2% of the total amount (*Ministério de Minas e Energia*, 2016a). Jointly with the largest population and territory (*Instituto Brasileiro de Geografia e Estatística*, n.d.), it is clear the importance of this country in the continent and so are the energy policies that its government implements for the development of the region.

The Brazilian economy, despite being the largest one in Latin America, has suffered an important crisis recently; in 2015 the GDP contracted 3.8% and energy consumption in the country decreased 2.1% (*Ministério de Minas e Energia*, 2016c). The growing projections have been shrunk in both fields between 2014 and 2024; the GDP yearly expansion went from 4.3%

to 3.2% and energy consumption from 3.7% to 2.7%. Nevertheless, the electricity consumption will increase in a 4.2% rate per year (*Ministério de Minas e Energia*, 2016b).

The Brazilian electrical model is supported by the government seeks, among other objectives, to guarantee electrical energy supply at an affordable cost as well as to promote social access to the electric system (*Ministério de Minas e Energia*, n.d.). The installed capacity of the country is abruptly dominated by hydropower with 91.65 GW, being 140.89 GW the total amount in the country (*Ministério de Minas e Energia*, 2016c). This source of energy contributed to 62% of the produced electricity of the country in 2015 followed by natural gas with almost 14% (*Ministério de Minas e Energia*, 2016c). It is remarkable the increase of wind production of electricity, which passed from 12.21 TWh in 2014 to 21.63 TWh, an increase of 77.1%. The total participation of renewable technologies in the energy matrix was 75.5% (*Ministério de Minas e Energia*, 2016c). Electricity imports of the country are very relevant, in 2015 they were 34.42 TWh, almost 6% of the total electricity consumption. Proportionally, the electricity produced in Brazil in hydropower plants is much higher than the installed capacity since this technology is used to cover the baseload demand while fossil-fueled power plants are run on to cover peak-load demand (Corrêa da Silva, de Marchi Neto, & Silva Seifert, 2016).

The droughts that the country has suffered in the middle of the 2010 decade have highlighted the risks of the heavy dependency of Brazil on hydropower (Corrêa da Silva et al., 2016) and its exposure to hydrological conditions, a situation that may become even worse with the current climate change previsions, increasing the energy vulnerability of the nation (Ruffato-Ferreira et al., 2017). It is noticeable that the participation of other renewable technologies has not been developed enough in a country as vast as Brazil with an enormous potential for wind and solar technologies development (M. G. Pereira et al., 2012). This condition opens a wide area of opportunity for further investments, in which some technologies like hydro, biomass and onshore wind are already competitive and some others, for instance solar and offshore wind, still require government incentives (A. O. Pereira, Cunha da Costa, Costa, Marreco, & La Rovere, 2013).

The Brazilian government is seeking to reduce its GHG emissions 37% and 43% by years 2025 and 2030, respectively, compared to 2005 (Portal Brasil, 2015). The electricity consumption in the country is expected to grow 50.7% and achieve 940.8 TWh by 2024. By its part, electricity imports should be reduced at an annual rate of 6.5% towards 2024 (Ministério de Minas e Energia, 2016b).

The participation of RE in the total primary energy consumed in the country is expected to achieve 45.2% by 2024, while the aim of their participation in electricity generation is to achieve 86% by 2024, dominated by hydropower, with a contribution of 65.8%. Other RE technologies are going to pass from a contribution of 9.4% today to a 20.4% by 2024 (*Ministério de Minas e Energia*, 2016b).

The Brazilian electricity system is highly integrated with its neighbors, possessing not only international transmission lines but also binational hydropower plants, like the Itaipu power plant with a capacity of 14 GW (*Ministério de Minas e Energia*, 2016a). Interconnections have helped Brazil to fulfill its energy needs and will continue to do so in an integrated South American energy market.

Regarding energy efficiency in the electrical system, Brazil has launched since 1985 the National Electricity Conservation Program, a Federal government program coordinated by the Ministry of Mines and Energy and implemented by Eletrobras, which promotes the efficient use

of electrical energy. This program covers areas of education, information, and promotion in both the private and public sectors. In 2015, this program allowed the country to save 11,680 TWh and avoided the emission of 1,453 billion tons of CO_2 equivalent (Eletrobras, 2016).

Within the Brazilian economy, a 1% increase of electricity consumption coming from RE sources would increase the GDP by 0.20% (Corrêa da Silva et al., 2016; Pao & Fu, 2013). So an expansion of RE would not only help to maintain low GHG emissions and boost economic growth, but also help the country's competitiveness and enhance its national ES. It is imperative for the country to focus on investments and efforts on energy efficiency, technological improvements and renewable sources (Almeida Prado et al., 2016), so the government may dimension properly the country's energy needs considering the cultural and wealth differences among its population (Zurn, Tenfen, Rolim, Richter, & Hauer, 2017), and fulfill them in a more efficient way, avoiding being jeopardized by environmental factors. At the end, a vast and natural-resources rich country such as Brazil should not have difficulties when it comes to energy matters.

Argentina

Argentina is the most important nation economically and demographically in the River Plate basin and it is also the barycenter of the regional electrical market (Wiegers, Institute for Latin American Integration., & Inter-American Development Bank., 1996). The country is hydrocarbons dependent and due to the current reduction in oil and natural gas reserves, it has seen its energy supply threatened (Recalde & Ramos-Martin, 2012), so the current national government established the promotion of renewable generation as a strategic objective for improving ES and mitigate climate change. As a country that , it is expected that energy consumption in the country increases in such a way that annual electrical energy demand will go from 135 TWh to 170 TWh in the mid-term (*Ministerio de Energía y Minas*, 2016).

Combined cycle plants together with gas turbines are the dominant technologies in the Argentinean power system summing 14.48 GW of installed power, followed by hydropower with 11.11 GW (*Comisión Nacional de Energía Atómica*, 2016). By its part, electricity generation in the country follows the same pattern as the installed capacity, being the preponderant sources of energy natural gas with a participation

of 47% of the total production, and hydropower with 31% of the 135.46 TWh produced in 2016 (*Compañía Administradora del Mercado Mayorista Eléctrico S.A.*, 2016).

Natural gas is a fundamental fuel for the energy mix, so the country is intended to expand its gas ducts both nationally and internationally in order to increase the gas trade. Additionally, the federal government jointly with the provincial ones plan to develop unconventional gas field projects, which shall increase importantly the country's gas availability (*Ministerio de Energía y Minas*, 2017).

Hydropower is the most important renewable source of energy in the Argentinean mix, representing the 70% of the renewable sources electricity production. Despite the fact that Argentina has one of the largest potentials for the development of wind and solar technologies in the region (Garcia-Heller, On Espinasa, & Paredes, 2016), those technologies achieved only a 0.4% participation of the total electricity production in the country in 2015 (*Compañía Administradora del Mercado Mayorista Eléctrico S.A.*, 2016).

A reduction of 15% of GHG emissions in a business as usual scenario towards 2030 is the current national objective and that reduction may be augmented to a 30% if necessary foreign aid is provided to the country (*República Argentina*, 2015). Argentina has the short-term objective of reaching 8% of contribution of renewable sources of the electrical energy consumption by the end of 2017 and a mid-term objective of 20% by 2025 (*Congreso de la Nación Argentina*, 2015).

The southern nation has electrical interconnections with most of its neighbor countries. In 2015 the country exported 55 GWh, all of them to Brazil, while 1655 GWh were imported, mainly from Uruguay (*Compañía Administradora del Mercado Mayorista Eléctrico S.A.*, 2016). The Argentinean electrical system, according to the Mercosur energy integration agreements, may dispose its lines for energy exchanges between Brazil and Uruguay.

In order to promote energy efficiency, the Argentinean government through the Ministry of Energy and Mining, has created a series of programs with which it is expected that the country reduces by 5.9% of its final energy consumption by 2025 compared to the current tendency (*Ministerio de Energía y Minería*, 2017) and move from 170 TWh to 158 TWh of electricity demand through efficiency measures (*Ministerio de Energía y Minas*, 2017).

It may be seen that the current federal administration of Argentina has the aim of transforming the country's energy mix towards greener alternatives as well as developing new interconnections and boost the use of local resources for fulfilling its energy needs. Despite the fact that the objectives of the country regarding energy efficiency and RE sources penetration are not as aggressive as other countries in Latin America, the current series of strategies in the country, if implemented adequately, may place Argentina as a new more investment-attractive economy with a stronger security of energy supply.

Germany

Germany has the most ambitious plan for transforming its energy system and it has called it the *Energiewende*. Considering that it is the largest economy and energy producer and consumer in the continent, we are talking about a very significant breakthrough, not only in the continent but in the world.

Fossil fuels are still the main source of the German electricity production, mainly coal with 49.8 GW of installed power, constituting 50% of the national production in 2016

(*Franhofer-Institut für Solare Energiesysteme*, 2016). Despite the fact of the important installations of renewable energy technologies, particularly wind and solar power, which are 49.6 GW and 40.85 GW, respectively, summed only 27% of the total national production of electricity.

The German *Energiewende* (energy transition) has two pillars: efficiency and renewable energies. Through efficiency, both in the producer and consumer sides, it is expected that energy consumption in the country decreases constantly in the incoming years, while the economic growth will continue to expand. This will lead the country to improve importantly its energy intensity at the time that electricity becomes the most important energy source in the country (*Bundesministerium für Wirtschaft und Energie*, 2016).

Renewable energies, as a result of the Renewable Energies Act (EEG), have been expanded in the country thanks to mechanisms that originally attracted investors to the sector mainly by guaranteeing their return rates in the sector. Today, it is considered that since the technologies have achieved a mature stage, they are able to compete on equal conditions with conventional energies (*Bundesministerium für Wirtschaft und Energie*, 2017). Moreover, the act stablishes specific targets to be achieved, specifically for the electrical sector, it should be between 40% and 45% for year 2030 and between 55% and 60% for 2040.

An important penetration of renewable energies in the power sector, such as the one Germany is suffering, requires, due to the internment nature of these energies, the deployment of storage facilities, as well as a better integration of the system, not only within its borders, but also with its neighbors. Particularly for the German case, the objective of phasing out completely its nuclear power plants by 2022 will represent new challenges for the electrical system, such as a larger dependence on external energy sources, which would prejudice the country's energy security.

Germany is now the global spearhead on energy transitions, since, despite its economic size, has decided to abruptly transform its energy system from a carbon-based one to a renewable one in a relatively short period of time. With such a changeover, new challenges arise, so the country will have to overcome them in order to maintain the leading position of the country in the region.

Each country defines its strategies for procuring security of its electrical system according to its own possibilities, needs and interests.

France

France is the country with the largest participation of nuclear power in its electricity production and, according to the objectives of the government, this situation will continue this tendency in the mid- and long-terms. 63.13 GW is the installed capacity of nuclear power, followed by hydropower with 25.48 GW (*Réseau de transport d'électricité*, 2016).

The most relevant law enacted in the country is the "Law Relative to the Energy Transition for the Green Growth" (LTECV) in 2015. It contemplates objectives for the mitigation of climate change and the reinforcement of

the national energy independence (*Ministère de l'Environnement*, 2016). Thanks to its implementation, this law has caused the expansion of renewable energies deployment. Probably one of the most important introduction of this law is the established limit of the nuclear participation of nuclear power in the electrical energy mix to 50%.

France is today one of the countries that exports electrical energy the most in the continent, with 39.1 TWh in 2016. Several of its neighbors rely heavily on the imports from France, so an abrupt transition to an energy mix based on renewables will require not only the adaptation of France itself, but also the neighboring economies must be prepared for this new paradigm.

Changing the energy matrix of a country so dependent on one energy source requires great efforts in order to transit to a more environmentally-friendly scenario. The case of France shows that, regardless of the fact of not renouncing its nuclear energy, the country commits itself to promote other forms of energy and to reduce its energy use. Some authors like (Morris & Pehnt, 2016; Quaschning, 2010) support the idea that nuclear energy is incompatible with a high penetration of renewable energies, so proving them wrong is a task that the French policy makers must contemplate for the future of their power system.

DISCUSSION

Different countries around the world take distinct approaches to enhance energy security in their territories, depending on their own current situations and the path they decide to follow according to their interests and possibilities. Notwithstanding, from the studied national policies, summarized in Table 1 (on the next page), several prevailing tendencies arise. Concerning the electrical energy system, three major international regimes are identifiable in the covered regions, which are the transition to renewable energies, the shale revolution and improvements on energy efficiency.

Every one of the covered countries places the deployment of renewable energy technologies as a priority for their energy policies in the long-term, as shown in Table 1. From these countries, Brazil is the nation with the highest objective on participation of renewables, with 86% of gross electricity consumption by 2024.

The European countries, which virtually lack of conventional energy sources, have more ambitious objectives for renewable energies deployment compared to those of America. Moreover, the French and German strategies place diversification and flexibility as priorities for procuring energy security. Improvements on flexibility are conducted through national and international electrical interconnections, in order to create an integrated system at a continental level.

But despite a relevant future penetration of renewable technologies, countries like the United States, Mexico and Argentina will still rely importantly on fossil fuels, particularly natural gas under the frame of the shale revolution. This trend is currently taking place in the American countries, since they are those possessing important amounts of shale fossil fuels, and are keen to draw upon these sources to enhance their energy security in the mid- and long-terms. Nevertheless, these countries have also taken an all-of-the-above strategy for an expansion of their power system, which would lead to a more competitive system supported by both fossil and renewable energy sources.

Among the covered strategies, efficiency also occupies a primary role. Two cases are identifiable, the first one is that of countries with mature economies, represented by Germany and France, and those with expanding economies, formed

by the countries in the American continent. For the case of European countries, they plan to reduce their primary energy consumption in the mid- and long-terms and to transfer a considerable amount of this energy to the power system. France in particular, plans to limit the presence of its nuclear energy in in energy mix, a very important paradigm considering the dependence of this country on this kind of energy.

Table 1: Summary of national energy objectives and year of accomplishment

		United States		Canada		Mexico		Brazil		Argentina		Germany		France	
		Target	Year	Target	Year	Target	Year	Target	Year	Target	Year	Target	Year	Target	Year
GHG reduction		17%	2020[3]	30%	2030[3]	30%	2020[2]	37%	2025[3]	15% *	2030	40%	2020[1]	40%	2030[1]
												55%	2030[1]		
		28%	2025[3]			50%	2050[2]	43%	2030[3]			70%	2040[1]	75%	2050[1]
												80-95%	2050[1]		
Final energy consumption reduction		ND		ND		ND		ND		ND		20%	2020[4]	20%	2030[6]
												50%	2050[4]	50%	2050[6]
Energy productivity increase		Double (2014)	2030	ND		1.9%/ year	2016-2030	ND		ND		2.1%/ year	2008-2050	ND	
						3.7%/ year	2031-2050								
Gross electricity consumption reduction		ND		ND		ND		ND		ND		10%	2020[4]	ND	
												25%	2050[4]		
Renewable energies penetration	**In primary energy consumption**	50%		2025				45.2%	2024	ND		18%	2020	23%	2020
												30%	2030		
												45%	2040	32%	2030
												60%	2050		
	In gross electricity consumption	State objectives		Provincial/ territorial objectives		25%	2018	86%	2024	8%	2018	>35%	2020	40%	2030
						30%	2021					>50%	2030		
						35%	2024			20%	2025	>65%	2040		
						37.7%	2030					>80%	2050		
						50%	2050								
Nuclear participation in total electricity production		ND		ND		ND		ND		ND		0%	2022	50%	2025

[1] 1990 base
[2] 2000 base
[3] 2005 base
[4] 2008 base
[5] 2011 base
[6] 2012 base
* Business as usual scenario
ND: Not determined

Source: Elaboration of authors

The American countries by their part, whose economies are expected to continue expanding in the long-term, plan to control their energy consumption growth through efficiency measures, which cover production, transmission and consumption. Particularly for the cases of Germany, Mexico and the United States, their strategies contemplate an enhancement of energy productivity through a series of measures that shall both improve economic growth and enhance their national security. This measure is particularly important since it helps determining the success or failure of implemented energy policies (Parker & Liddle, 2017).

From the studied countries, Germany is the one with the most ambitious and most methodologically-developed strategy in order to enhance its energy system; its plan is stated towards 2050 and covers from GHG emissions and renewable energies deployment to efficiency and consumption, not only in primary energy and electricity consumption but also in final energy productivity. The German *Energiewende* has served as a model for distinct economies in Europe and around the globe to re-shape their whole energy systems to new ones based on renewable energies and high-efficiency along the whole energy chain, being these two precisely the pillars driving the German energy transition.

CONCLUSIONS

There does not exist a single strategy for procuring a nation's energy security, but every country establishes its own approach in the matter according to its own possibilities, needs and interests. Nevertheless, international regimes, such as the fight against global warming, tend to shape energy policies globally.

Energy transitions have taken electricity to become the pillar of current energy systems, and it will acquire even more importance in the long-term, so guaranteeing a secure power system is crucial for achieving sustainable development. Hence, energy security in the power system constitutes an utmost importance element within energy policy.

The transition to renewable energy sources is an extensive trend to be conducted through the deployment of new installations. However, how these technologies will be deployed and to which extent are highly dependent on geological and geopolitical circumstances.

Apart from the installation of renewable energy power plants, for a successful energy transition it is necessary to improve flexibility and efficiency of the power system. Flexibility is fundamental for the integration of renewable energy technologies, since it helps counteracting their intermittency and heterogeneity, while efficiency contributes to the correct dimension of power plants and reduces the waste of energy along the whole chain.

Among the covered countries, there can be identified two different major approaches for procuring energy security, the first one followed by European countries and the second one by the American ones.

Countries in Europe promote importantly the use of renewable energies, a totally understandable aim since fossil fuels are practically absent in the region. This fact has taken the countries in the continent to launch important energy transition paths that, besides renewables deployment, cover improvement measures of efficiency and flexibility. Moreover, shifts on their energy mix are also covered in their respective strategies; France, a today's heavily dependent nation on nuclear energy, plans to limit the presence of nuclear power in its electricity mix, while Germany intends to shift its heavy dependence on coal to renewables, particularly wind and solar, while totally phasing out its nuclear plants by 2022. Nonetheless

and despite the fact that these are very important steps for their respective energy transitions, these countries will still rely heavily on conventional and foreign fuels in the mid- and long-terms, so efficiency, diversification of fuels and sources as well as interconnections are also imperative for guaranteeing their energy security.

America has a very different approach than the one of Europe, since the countries this region can be considered relatively rich on energy resources, due to their size and a more advantageous geographical situation.

The largest economy in the continent, the United States, has developed an all-of-the-above strategy for procuring its energy security, an effective way of becoming energy independent through the exploitation of all its indigenous energy sources to the extent of possible. The country has no priority on shifting to a mostly-renewable energy mix, since the large reservoirs of fossil fuels it possesses, shale in particular, guarantee energy access in the country even in the long-term. Nevertheless, the United States has some of the largest renewable energy installations in the world, and it is a pioneer on technology development for both fossil fuels exploitation and renewable energies use. Additionally, several efficiency measures are taking place in the country, all in order to improve national energy productivity as a key measure for the improvement of energy security within its borders.

Canada and Brazil have similar approaches concerning their energy transitions; since both have currently an important share of renewable energy in their total electricity production thanks to hydroelectric power plants, their strategies consist basically of partially moving this hydropower electricity production to other renewable energy forms, particularly wind and solar power plants, along with improvements on efficiency. By their part, Mexico and Argentina follow similar scopes on their power systems, both depend mainly on natural gas for producing electricity, both plan to increase the presence of renewable energies, yet Mexico more ambitiously, and both plan as well to exploit their fossil conventional and non-conventional sources as a primary measure for improvement on energy security.

Due to the diversity and complexity of the different analyzed strategies, it results necessary the establishment of a clear frame with defined boundaries in which the concept of energy security is applied to the power system, as well as a series of parameters that could be used for measuring the effectiveness of these strategies for achieving energy security. This frame would lead to a methodological tool for policy makers to develop sustainable stratagems in order to achieve sustainable development.

Countries tend to develop "all-of-the-above" strategies for securing their energy supply, though renewable energies deployment and efficiency are the most widespread approaches.

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