EXPERIENCES OF MIDTERM PLANNING IN THE COLOMBIAN ELECTRICITY SYSTEM

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Worldwide, countries are developing climate change policies to enable them to meet the nationally determined contributions (NDCs) they pledged in the context of the Paris Agreement. Questions and problems arise when transitioning to the implementation phase. One of the main questions is how to attain results quickly under institutional frameworks that are insufficient to address climate change; as a response to this lack of institutional clarity, and to start the implementation phase as soon as possible, many countries are creating links between low-carbon intensive policies (such as renewables or reforestation) and climate change. In the electric energy sector, due to its cross-cutting nature in the economy, planning the expansion and operation of the grid is vital and must take into account the nature of the required energy matrix and its mitigation potential, but, most important, it must find appropriate ways to introduce new technologies while reducing associated risks to grid breakdowns and guaranteeing social well-being.

Although planning might have less impact in some countries, in ones with institutional weaknesses and limited (or diminishing) resources, actions (and results) benefit from long-term planning rather than a demand-based response that simply reacts to crises. Using the Colombian case as benchmark, this case study discusses the evolution and performance of national electrical matrix planning, as well as the main challenges faced under the increasing stress brought by climate change.

OVERVIEW

In the early 1990s, Colombia suffered an extreme drought that caused nationwide programmed blackouts of up to 10 hours daily. The water scarcity took a toll on the country's economy, lowering the gross domestic product by approximately half a point (Farah 1992) and bringing on a political crisis that led to a total reengineering of the national electrical system.

As result, and with the main objective of increasing the system's resilience to avoid further blackouts, the Colombian government asked for long- and midterm planning tools able to forecast expected electricity demand, as well as the infrastructure required to fulfill it. With this in mind, Law 143 of 1994 gave the Ministry of Mines and Energy (MME), and its newly created agencies, the responsibility to produce and periodically update a National Energy Plan (NEP)

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for the long-term view and a Reference Expansion Plan (REP) to guide the midterm growth of interconnected electrical systems in the country.

The MME was given responsibility for planning the expansion of the national grid, taking into account the expected electricity demand, the required expansion of the generation matrix, and private generation projects in the pipeline, additionally revising criteria for transmission and distribution. In 1992, the government released a plan that focused on short-term actions in order to mitigate the effects of the crisis, focusing on emergency investments for the period between 1992 and 1995. In 1993, and in the context of discussions of the new laws, the MME submitted the first revision of the expansion plan and proposed a midterm expansion period from 1993 to 2010 (Interconexión Eléctrica 1993). As a result, the 1993 revision may be considered the first midterm Reference Expansion Plan under Law 143. Subsequently, 17 revisions have been released (see Table 1), each providing updates of future demand, as well as information on registered electricity projects, economic factors, and CO_2 emissions. Hence, the REP can be viewed as one master plan that is continuously updated.

In contrast to the NEP, in which the MME states "basic" principles and vision for the long-term expansion of the system, the REP is based on midterm forecasts of electricity demand that take into account expected economic growth, demography, expected price of energy commodities, available technologies, expression of interest in electricity generation, and climate variability. As many of the input variables are subject to "deep" uncertainty, the prediction capabilities of the REP are always under scrutiny; this essay will argue that planning is a learning process, and that the revision exercises (updates) have improved the MME's institutional capabilities, reducing uncertainty and allowing for better policy design. It is important to mention that since 2006 there has been a shift in mentality, as efforts to expand the generation matrix have started considering CO_2 emissions and the use of nonconventional renewable energy (NCRE), bringing the country valuable know-how.

The purpose of this case study is to focus on the REP's influence on the structuring of the current energy-generation matrix, which looks to enhance the system's reliability and coverage under the current scenario of climate variability, as well as the commitment of the electricity sector to reduce its emissions. It will also discuss the evolution of the REP; as it has developed, the REP has started considering a new pillar, the environment, under a new set of regulatory changes in order to address and fulfill the NDC that Colombia presented at the COP21 and later ratified. This case study is a first step in trying to analyze the impact that the REP and its updates have had on the electrical system in Colombia.

INTRODUCTION

The Reference Expansion Plan is the main instrument for midterm electricity matrix planning ("midterm" in this case refers to periods between 5 to 15 years, but this may vary according to the revision considered) and is revised periodically (annually since 2008) taking into account variables such as hydrology, demand forecast, current state of infrastructure, and approved generation projects with financial guarantees. This exercise has helped increase the system's flexibility and reliability under changing technical, economic, financial, and environmental conditions.

The objective of the REP is to guide the expansion of the electrical grid with a midterm horizon, providing information about projected demand and electricity projects registered in the information bank of the newly created Mining and Planning Unit (UPME).

Due to the crisis experienced in 1992 and growing concerns about the reliability of the electrical system, in 1994 Congress approved Laws 142 and 143, whose aim was to create a more dynamic market by allowing private companies to participate through a new set of rules for generation, transport, and electricity distribution. The reengineering of the system sought to increase the installed capacity and reduce dependence on hydropower generation (Figure 2) by allowing private companies to participate in the electricity market. The goal of this new vision was to diversify the energy matrix while reducing public investment (Government of Colombia 1994).

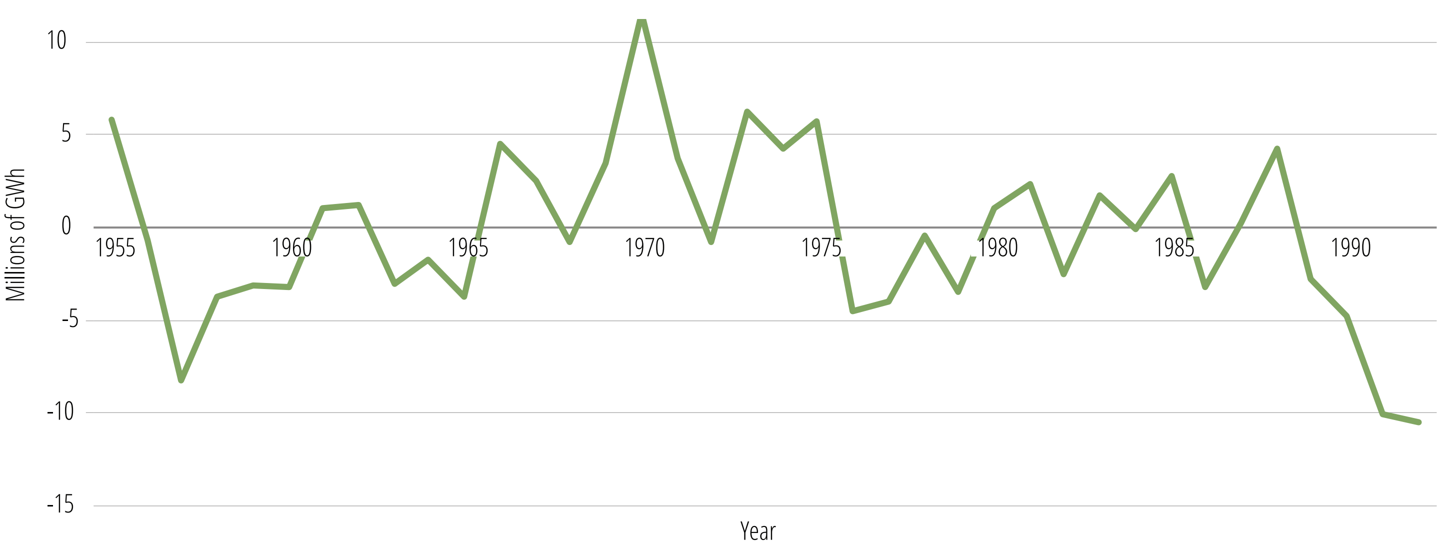
In addition to creating a new market, the government imposed a set of requirements regarding the use of data for estimation of the country's demand and the subsequent expansion plan. In other words, Law 143 enabled the Ministry of Mines and Energy to adopt a midterm plan that all interested parties could use as a guide with recommendations from the UPME.

Article 12 (of Law 143) established the requirements for midterm planning, asking for improved adaptability to changing conditions under the expected demand, based mainly on the objectives of technical, economic, and environmental feasibility. In line with Article 12, Article 16 gave the UPME the mandate to periodically update the REP and present it to the Ministry of Mines and Energy to be adopted by ministerial resolution. The REP updates are adopted by resolution, creating an implicit consultation process where different entities (the private sector, other government branches, higher education and innovation institutions) are able to present their comments before its formal adoption. However, the technical complexities of the updates as well as time constraints limit public participation in the process. It is important to note that the REP updates nonetheless are strongly based on information obtained firsthand from the electricity generation sector and the electricity market; the requirements of the private sector are always taken into account and play an important role in structuring the future energy matrix.

NATIONAL CONTEXT

Prior to 1993, the Colombian electricity system was mostly state owned and expansion plans were prescriptive in terms of new capacity and technologies. Planning was centralized with a marked disregard for transmission and distribution systems (Interconexión Eléctrica 1993). In 1991, the National Electricity Commission approved a new expansion program that required an additional 2,000 MW to cover the increasing national demand. However, the 1992 drought and energy crisis brought on by sharply reduced hydrological generation (Figure 1), as well as new internationalization and privatization policies, led the National Electricity Commission to request an updated planning strategy with prediction models that would improve understanding of midterm demand, integrating transmission, environmental, and other additional variables, under the assumption that the long-term view would be addressed by the NEP.

Figure 1. Hydrological Generation



Source: Interconexión Eléctrica (1993, 21).

As the Colombian government did not have the technical capabilities to start a comprehensive planning process, Interconexión Electrica S.A. (ISA) was commissioned to revise and update the short-term objectives proposed in 1992, as well as generate a midterm plan. In 1993, ISA presented this plan for the 1995–2004 time period. This first REP sought to increase the system's flexibility through the following objectives and guidelines, to be followed in future REP updates:

- Use reference (indicative) planning instead of prescriptive planning.
- Establish the satisfaction of national demand as the main objective.
- Integrate and consider both the national electrical system and the national transmission system in planning.
- Consider the additional variables of efficiency, environmental impact, safety, and reliability.
- Foster efficiency (price efficiency), private participation, and competition.
- Promote market-oriented planning.
- Reduce system vulnerability by diversifying technologies and creating new generation geographies, interconnections, and risk-assessment methodologies.
- Make planning lean to optimize resources.
- Incorporate macroeconomic and financial feasibility in the analysis.
- Stress environmental feasibility to guarantee the viability of projects in certain ecosystems.

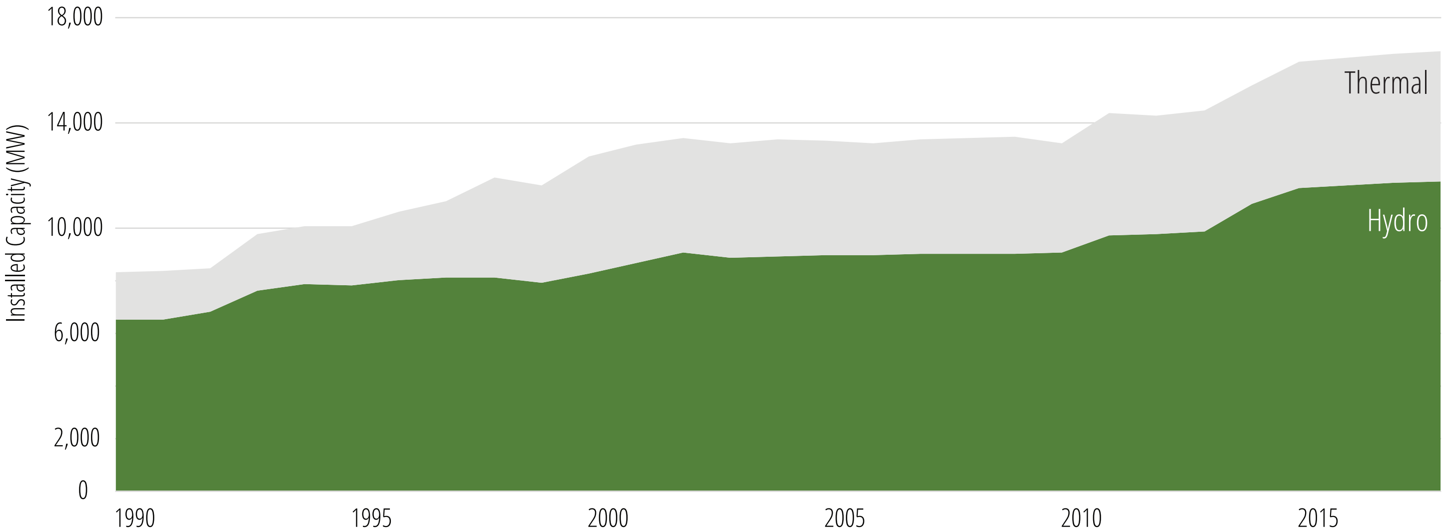
These objectives have remained over time, but what can change from update to update is the level of importance assigned to each of them. In order to achieve its objectives, the 1993 REP focused on the need not only to expand the national generation matrix and transmission grid but also to create new institutional arrangements between the Ministry of Mines and Energy and three new institutions: the Energy and Gas Regulatory Commission (CREG), in charge of techno-economic regulation; the UPME, in charge of planning, and the Superintendence for Public Services, charged with oversight and consumer protection. The first REP emphasized the need for the following:

- A new regulatory framework enhancing the oversight capabilities of the Ministry of Mines and Energy
- Energy efficiency as a key factor in planning
- Better planning tools and new methods that provide better estimations and simulations
- Research and innovation as a key component in system expansion
- A new regulatory framework for tariffs and other incentives to make new investments more financially viable

The 1993 electrical market reform has generally met the country's expectations in terms of reducing the government's financial burden and debt, and increasing the transparency of tariffs and convergent unitary production costs. Additionally, the generation matrix has become more diverse, with the share of hydropower going from 78 percent in 1993 to 70 percent by 2018. This reduction in installed hydropower capacity is considered important due to the idiosyncrasy of Colombia's electrical system, with its hydrological resources that are abundant and relatively cheap (compared to other fuel sources). This decreased dependence on hydrological resources has had positive and negative consequences. In principle, the country has become less vulnerable to climate variability by incorporating mainly thermal generation systems (see Figure 2). However, these efforts have not been sufficient to guarantee energy security during events of extreme climate variability (see Figures 5 and 6, year 2015). The country is still highly dependent on hydrological conditions, a concern brought to the foreground by recent events (including the intense drought of 2015).

Government actions have focused on satisfying demand with price efficiency, assuming that the market is the best way to ensure reliability. This assumption has not been completely borne out, as the system has not been entirely reliable or price efficient.

Figure 2. Historical Installed Capacity



Source: XM.[4]

OVERVIEW OF THE PROCESS

With a view to achieving appropriate levels of supply to meet electricity demand, the UPME is charged with performing an in-depth analysis of the current state of the Interconnected System[5] and setting out guidelines to shape the new energy landscape. The Reference Expansion Plan (with its updates) is the main instrument for midterm planning and is revised annually to account for changes in hydrology, demand, and the state of infrastructure, as well as the approval of generation projects with financial guarantees. This exercise has helped increase the system's flexibility and reliability under changing technical, economic, financial, and environmental conditions.

The Reference Expansion Plan follows a general process that uses forecast projections of electricity demand based on expected economic growth (macroeconomic variables), demography, expected price of energy commodities, available technologies, time of deployment of projects, and climate variability in order to produce a set of scenarios that are later consolidated through a quantitative (simulation) and qualitative analysis. Each iteration of the REP defines the time frame of the expansion plans; since 2008 this has been set to 15 years, but this has varied over time (see Table 1). Each iteration modifies the previous one (e.g., quantity and composition of the expansion, delay and changes in current and future projects), so the actual effect of a single expansion plan is not tractable. Some insight may be obtained from a comprehensive study of all iterations of the REP, analyzing expansion trends and defining periods that suggest changes in strategy (i.e., shifts in the expansion "philosophy").

The REP is a dynamic process that requires modeling and information to improve its predictive capabilities. Although planning has had three pillars in mind (quality, reliability, and safety), increased environmental concerns by stakeholders has made the system's emissions factor a decision variable. In fact, since the 2014 update, the UPME has enhanced the technical analysis abilities of each scenario's emissions factor, hence sending a message that emissions are a fundamental consideration in expansion.

Energy requirements are established via estimations of the growth in domestic demand (see Figure 3). The REP updates are intended to set out a roadmap that guides the actions of both government and private investors, as well as providing information for long-term planning addressed by the National Energy Plan, a document that offers a comprehensive, long-term view (over 30 years) of expected trends in not only electricity but also mining and hydrocarbons. The process of revising the REP follows these steps:

- Input information is obtained from sources including the Ministry of Finance, the National Department of Planning, and the MME. The core information is related to forecasts of economic growth (i.e., macroeconomic variables), demography, and fuel prices.

- The current state of the network is analyzed, including ongoing projects, possible delays, and system restrictions (mainly concerned with the transmission system).
- Based on the information obtained and on consolidated information of previous years, a demand forecast is produced.

Consequently, a baseline expansion plan and alternative scenarios are generated and simulated using computational and statistical tools. Each expansion scenario consists of the proposed expansion and its composition (e.g., the amount of nonconventional renewable energy, hydro- and thermal power); ongoing and future expansion projects, including delays and other considerations; and other environmental, political, or technical constraints. Some of the outputs are electricity prices, reliability, coverage, and technical concerns with the operation of the system.

A process of consultation with different sector companies and associations is performed to establish the possible expansion scenarios with best acceptance and performance and to approve the Reference Expansion Plan. However, is important to note that there is no specific requirement that the UPME consult with stakeholders or with other government agencies before the MME formally accepts the REP.

The method of general scenario validation and performance analysis is based on high-fidelity simulations with specialized software that takes into account such issues as hydrology, demand, fuel prices, transmission network constraints, and project delays. Reliability indicators are compared to the established metrics: the expected value of energy rationing (VERE) and the conditioned expected value of energy rationing (VEREC). The upper bound on the VERE and VEREC indicators are 1.5 percent and 3 percent, respectively, for a 95 percent guaranteed supply of energy. The main drawbacks of the reliability analysis performed are the uncertainty in the input parameters and the lack of international reference. The first issue is inherent to the midterm planning process and can only be overcome with better estimations and predictions of future values of the variables of interest (especially demand and hydrology estimations). The second issue may be resolved if more conventional metrics are used, such as the System Average Interruption Frequency Index, the System Average Interruption Duration Index, and the Momentary Average Interruption Frequency Index.

Once the MME accepts the REP update, it is adopted by ministerial resolution and the guidelines and recommendations in the REP are used by different agencies to guide their decision-making. If the REP update shows a gap between the current and the required installed capacity, the CREG can initiate a bidding process for new generation projects in order to fulfill this gap. Since the required (future) installed capacity is determined based on predictions of demand, overestimation (and underestimation) may result in overinstallation (or underinstallation) of the generation matrix. As shown in Figure 3, the demand expectations from the late 1990s and early 2000s were quite high, leading the CREG to open auctions for new projects that resulted in high installation in 2010 (Figure 2).

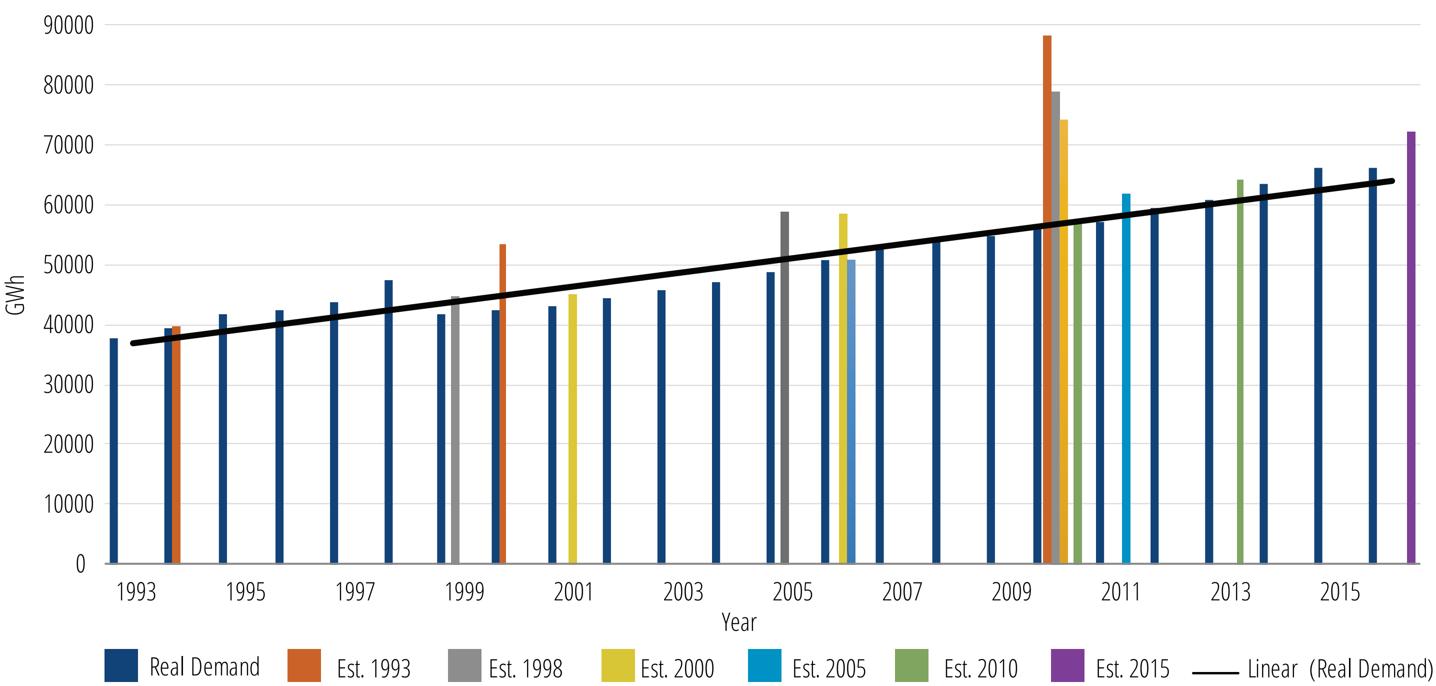
GOALS AND RESULTS

A forecasting tool is only as good as the information and models it uses. As Figure 3 shows, the first REP updates tended to overestimate future demand, with the 1993, 1998, and 2000 revisions of the REP off by up to 36 percent in their forecast for 2010. Demand forecasting has improved its prediction results as more iterations of the REP are generated. This seems logical, given the inherent learning curve over the course of which the parameters used for forecasting are adapted and fine-tuned. The 2005 and 2010 versions of the REP, for example, include errors no larger than 8 percent.

Figure 4 presents the evolution of electricity tariffs, brought to present value, for the period 1995–2016. The prices present expected dynamics, with values varying mainly due to climatic conditions; basically, Figures 4 and 5 show that the noticeable increases in 1997 and 2015 reflected an intense El Niño and Southern Oscillation (ENSO) phenomenon.[6] In 2000–2009 prices remained stable with a medium approximate value of US$110 per KWh. It must be noted that the increase in tariffs of 2015 is very large compared to the surge in 1997, increasing prices in nearly $300 per KWh, compared to the trend of 2000–2009.

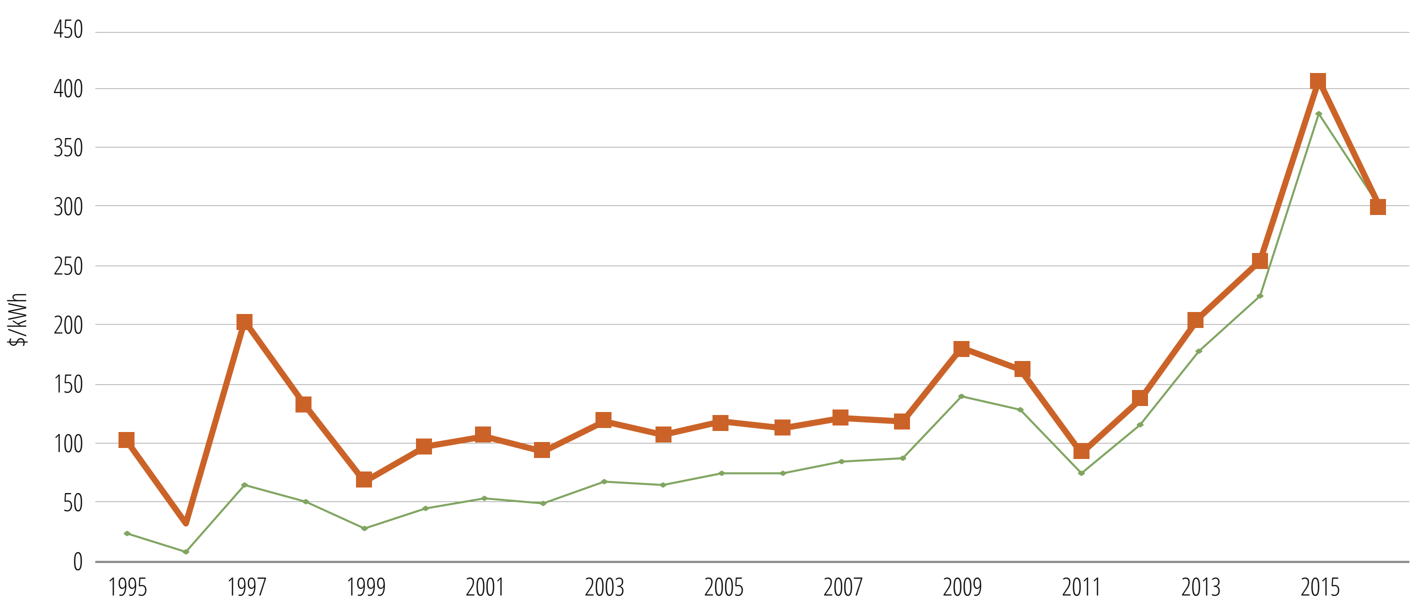
The overestimation of demand may have led to an excess of expansion projects of the national electrical system between 1993 and 2010. This, combined with the intense ENSO of 2015 (see Figure 5) and the reduced gap between available demand and supply (available energy), had a detrimental impact on energy prices (Figure 4), increasing tariffs for the end consumer due to the necessity to pay for the large investments made in generation and transmission (see Figure 4) and the failure to cope with intense climate variability and increasing demand.

Figure 3. Estimated Demand in REP (Scenario with High Demand) versus Real Demand



Source: XM.

Figure 4. Historical Electricity Price, Annual Mean Value



In fact, even without El Niño, prices began rising in 2011, when the amount of captured (cheap) hydroenergy was not enough to meet demand, requiring the use of more expensive (thermal) sources. Although Colombia achieved its reliability goals by 2010, this was not accompanied by price efficiency and sustainability, as seen during the events of 2015.

CLIMATE AS A DECISION FACTOR

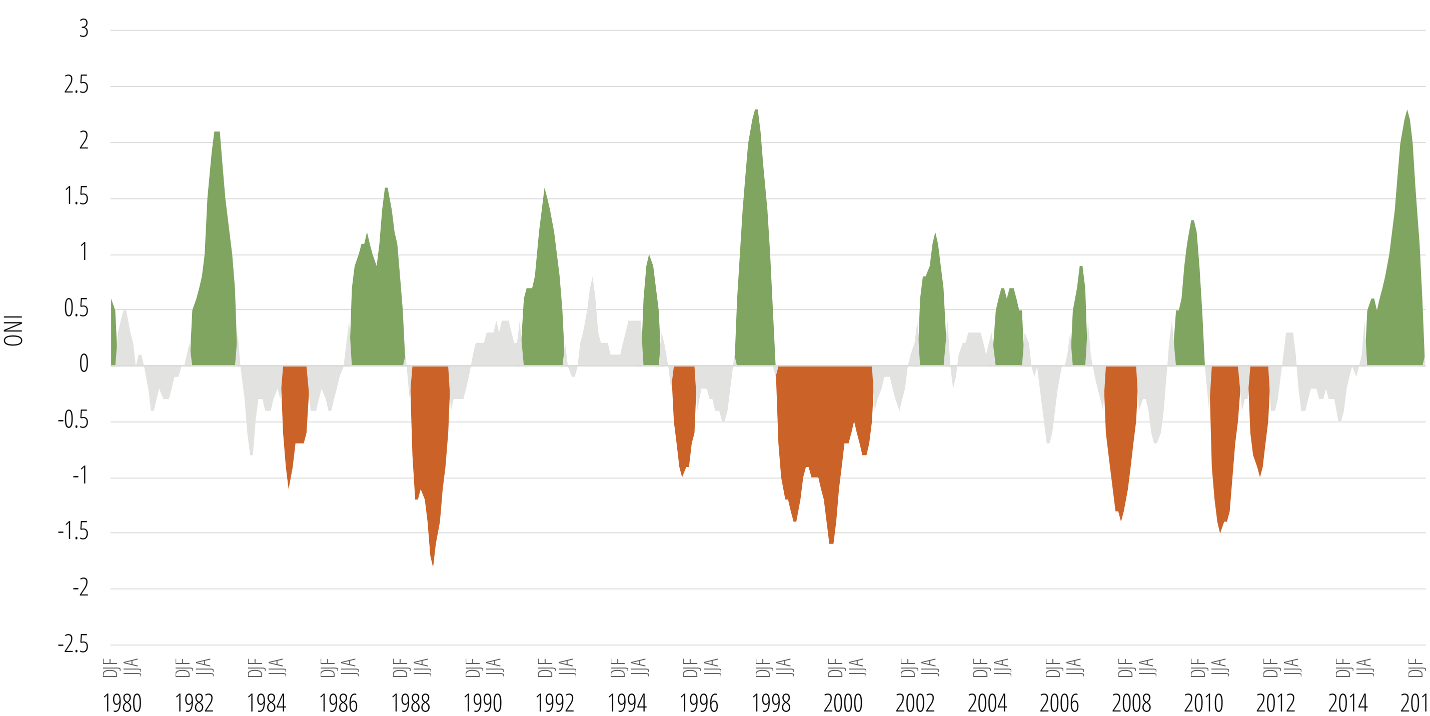
The safety and reliability of the Interconnected System can be considered in general to result from the diversification of the generation matrix in response to the (estimated) growing demand and projected ENSO. Unfortunately, until recently the system's efficiency has not been a criterion for reliability, which again has become a national concern (mimicking the difficulties of 1992) due to the extreme climate variability we now experience. As Figure 5 shows, the ENSO phenomenon (in green) has become more frequent and intense, and positive hydrology (plots with negative values, in brown) less abundant. This implies more frequent use of the thermal backup, with consequent increases in emissions and price.

Despite the system's expansion, actual available energy has been growing at a slower pace than demand and installed capacity, putting the system's reliability at risk due to a still-high dependence on hydropower. Figure 6 shows the net hourly generation versus daily demand over the last 18 years. Two interesting observations can be made: first, the gap between supply and demand has shrunk significantly since 2008, implying that electricity is more scarce in the country; second, the availability of electricity (a 30% increase in available energy compared to 2010) has not expanded as quickly as installed capacity (which grew approximately 50% during the same period).

Colombia faces a risk today, since even though national installed capacity has grown considerably, the country's dependence on hydrological resources (and the current uncertainty about possible intensification of the ENSO phenomenon) has prevented available energy from keeping pace. In other words, the country was barely able to cover demand, mimicking the situation it experienced in 1992, when supply almost matched demand (Figure 6), and bringing under scrutiny the different actions taken by the government and the REP, in particular the delays in the expansion plan and the lack of a well-tailored reliability action plan.

This has brought to the foreground the vulnerabilities of a generation matrix where hydropower dominates and thermal generation is considered mainly as a backup system. It also

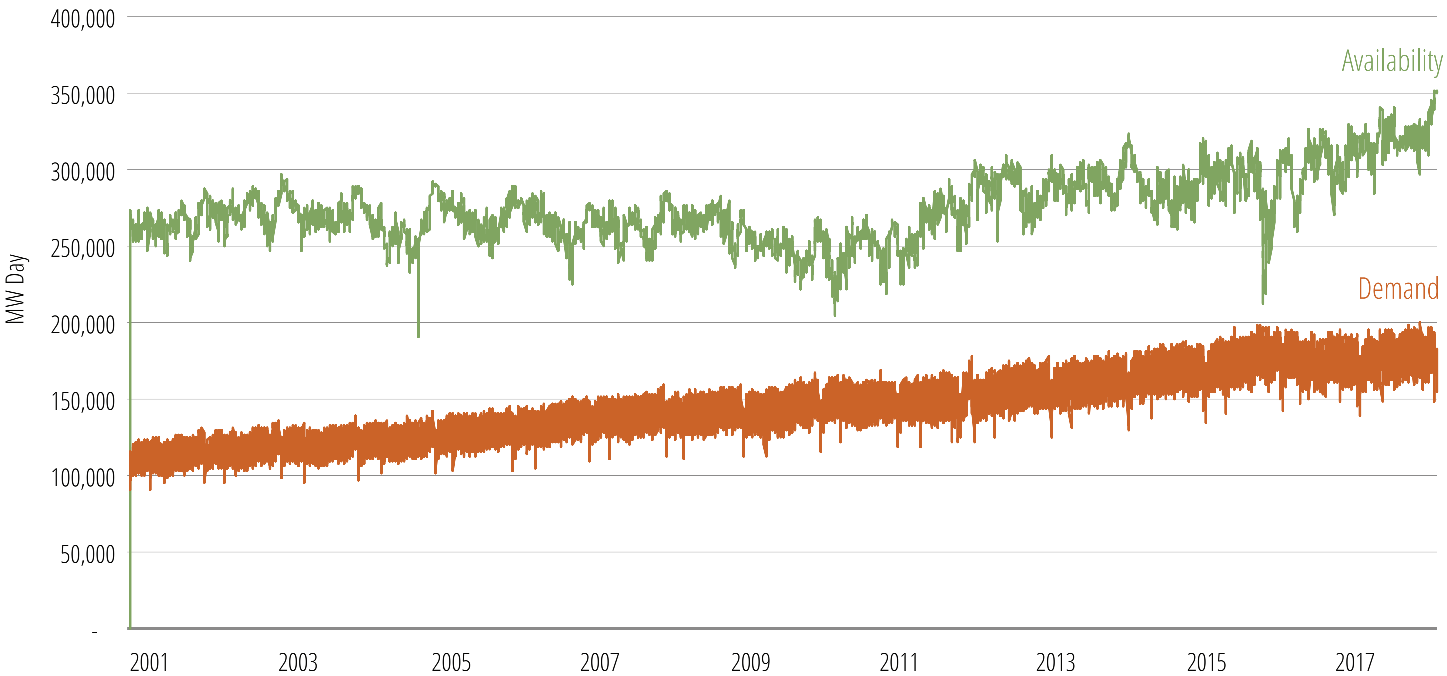
Figure 5. ENSO Correlation by Year (X Axis) in Colombia and the Oceanic Niño Index (Y Axis)



Notes: Positive event (green) denotes an ENSO phenomenon onset; negative values denote the "La Niña" phenomenon (brown); gray areas denote neutral conditions.

Source: NOAA (2018).

Figure 6. Real Availability versus Electricity Demand



Source: XM.

has reopened the discussion about diversity and reliability. In addition to the general concerns we have already mentioned, climate change is now at the center of the analysis, due not only to climate variability that affects market stability but also to the ongoing discussions within the United Nations Framework Convention on Climate Change (UNFCCC) on nationally determined contributions.

PLANNING FOR THE TRANSITION

As we have previously noted, the 1993 plan concentrated on improving the system's capacity for midterm demand fulfillment by enhancing flexibility and reliability. At this stage the country was favoring power-supply reliability (increase in number of thermal power plants, hence matrix diversification) rather than energy reliability (initially obtained through large-scale hydropower projects that store large amounts of hydraulic energy). In 2005 the UPME began observing that even though power reliability had been achieved, the country was still vulnerable to other exogenous variables (fossil fuel prices, the world economy, etc.). As a consequence, in 2005 Colombia changed the way it addressed the system's reliability, again beginning to favor hydropower.

After 1993 and the electrical market reform, reliability was considered as a capacity issue; that is, reliability was achieved thanks to a sufficiently large generation matrix, and the government imposed a premium financial resource to guarantee installed capacity. The Capacity Charge estimated the energy needed to maintain a stable market price under uncertainty and, through an auction mechanism, established short-term contracts with companies that trade profit for security. At this point, only capacity needed to be demonstrated. After 10 years of being applied, this strategy proved to be inefficient, failing to guarantee supply reliability and endangering large infrastructure investments. In 2006, the government, represented by the Ministry of Mines and Energy (as head of the CREG), introduced the Reliability Charge (RC), which was a change in paradigm, where the price paid for this required reliability was determined by market dynamics and imposed additional obligations on companies that wanted access to such financial stimuli (e.g., firm energy requirements). The government in turn could use this energy to regulate prices and keep them from exceeding a determined threshold known as the scarcity price.

Within the RC framework, the market price for energy is established and a short-term contract is assigned to the companies that offer the best bids. The companies granted RC contracts receive a fix price for their stored energy, avoiding the uncertainty of the market. The RC is a way to regulate prices and protect both consumers and providers, and going from a capacity-based reliability measure to a bidding paradigm for energy reliability had the following notable effects:

- It resolved issues of ill-posed conditions of reliability; capacity in ENSO events was exchanged for firm energy that may be used in any market situation that requires it.
- It increased market dynamics, since companies now must compete for RC contracts.
- It increased investors' interest by giving a financial stimulus to large-scale energy projects.

Before 2005, the REP exhibited a strong tendency to favor fossil fuels over hydropower (see Table 1). This increased flexibility (measured as the diversity of energy sources) but also prices and environmental impact. Between 2005 and 2014, the country favored hydropower, mainly due to concern about energy security and the newly established RC. Although this decision was mostly based on prices and energy reliability, it was strongly influenced by the Kyoto Protocol and the available domestic opportunities for Non–Annex I countries to obtain tax exemptions for Clean Development Mechanism (CDM) projects. In 2016, of the 69 CDM projects Colombia registered with the UNFCCC, 19 were related to hydroelectricity production (Ministry of Environment and Sustainable Development 2016).

In accordance with the nationally determined contribution (NDC) Colombia presented at the COP21, since 2014 the REP has included, and recommended, expansion scenarios with a high component of nonconventional renewable energy (NCRE). The 2014 REP was the first to incorporate a considerable amount of NCRE (the distribution by type of energy is similar to that presented in the 2015 REP, Table 1). The national electrical system managed to reduce its dependency on hydropower (compared to 1992) by almost 8 percent, but it is not clear if the system has reached the desired level of reliability. In fact, notice that generation by fossil fuels has regained a prominent role in the most recent iterations of the REP due to worries about climate and fuel price variability; as expected, the mix of power

Table 1. Proposed Scenarios of the REP

REP	Midterm Expansion Period	Expansion Scenario (Increment in MW)	Composition of the Expansion for the Proposed Scenario by the End of the Expansion Period		
			Hydropower (%)	Thermal power (%)	NCRE (%)
1993	1995–2004	3,982	30	70	—
1996	1996–2010	6,256	32	68	—
1998	1999–2010	2,564	35	65	—
2000	2005–15	3,720	39	61	—
2002	2002–11	1,810	36	64	—
2003	2003–12	1,460	45	55	—
2004	2004–18	1,160	57	43	—
2005	2005–19	980	67	33	—
2006	2006–14	997	79	21	—
2008	2008–22	6,278	45	55	—
2009	2009–23	8,076	75	25	—
2010	2010–24	6,278	82	18	—
2011	2011–25	7,914	77	23	—
2012	2012–25	—	—	—	—
2013	2013–27	7,093	76	24	—
2014	2014–28	3,451	40	35	25
2015	2015–29	5,116	30	33	37
2016	2016–30	4,569	40	27	33

Source: UPME (2018).

sources is more diverse and balanced, integrally addressing issues related to power-demand reliability, reliability of energy capacity, and GHG emissions.

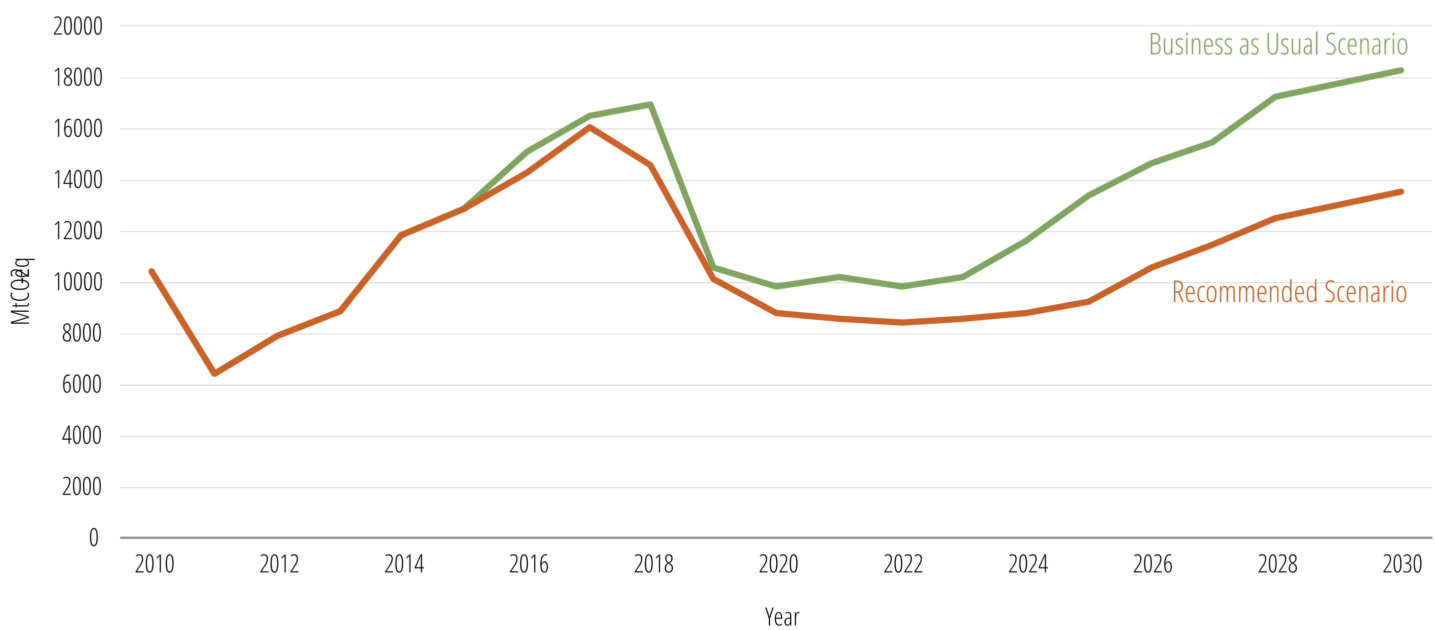
Law 1715 of 2014[7] also had a major impact on the promotion of NCRE projects, offering fiscal incentives (tax exemptions, accelerated depreciation of assets) to new generation projects. This impact can be seen in the increased new proposed participation after 2015.

The El Niño event of 2015 brought Colombia to the verge of another apagón (series of programmed blackouts). Interestingly, even though the country had sufficient installed capacity, a set of unfortunate events and operational problems with backup thermal plants and dams left the system barely able to meet power demand (see Figure 2). This put tremendous stress on both the system and the electrical market, as production prices rose to levels that surpassed the imposed scarcity price, leaving thermal backup systems without economic incentives to produce demanded electricity. Although most of the additional costs were transferred to the end-user, this event signaled the fragility of the current electrical system. Unlike 1992, however, when climate was a constant to be dealt with by proper planning, in 2015 uncertainty brought by climate variability and insufficient diversification was seen to be the main stress on the system. As a result, reliability was recognized as requiring not only a larger and diversified matrix but also efficient operation and maintenance.

Responding to these challenges, and with the advances in NCRE in mind, the 2014 REP presented for the period 2015–2029 an intended expansion of 5,516 MW with 37 percent of NCRE; for the first time, due to the private sector's expressed interest and the need for diversification signaled by the REP updates, the country has recognized this type of technology as economically viable for the coming years and, with the approval of Law 1715, sent a signal to the private sector about the government's interest in matrix diversification with new technologies. In 2018, the Ministry of Mines and Energy has taken a step forward with Decree 570, which asks the CREG to design a regulatory framework for the integration of an additional 1,200 MW of NCRE into the grid by the next decade.

One of the most important collateral benefits of the existence of the REP is the capacity of the electricity sector to understand its CO_2 emissions in relation to the efforts needed to fulfill the 20 percent reduction commitment in Colombia's NDC. As shown in Figure 7, the Colombian government used the 2014 REP to establish the sector's emissions baseline (business as usual) and the expected contribution. At the same time, the REP updates have helped the Ministry of Mines and Energy understand the mitigation potential and subsequent policies needed to help achieve the Colombian NDC (Government of Colombia 2018).

Figure 7. Emissions Baseline (Business as Usual) versus Projected Generation with NCRE Projects



Source: Ministry of Mines and Energy (2017).

According to the Colombian Ministry of Mines and Energy, the electricity sector is able to reduce its emissions by around five megatons CO_2 equivalent, accounting for more than 40 percent of total sector reductions (which include emissions due to mining and fossil fuel production) by 2030 (see Figure 7) (Ministry of Mines and Energy 2017). In early August 2018, the Ministry of Mines and Energy formally introduced (by resolution) the Integral Plan for Climate Change Management (Ministry of Mines and Energy 2018), which provides guidelines for strategic action required to reduce emissions. As in the 1993 REP, three of the four strategic lines address basic concerns about electricity diversification, energy efficiency, and demand response.

LOOKING FORWARD

Uncertainty, always detrimental, is the reason why Colombia has chosen to develop certain policy guidelines, such as the REP, to reduce it. This case study has shown the context and motivation, as well as the process, that have driven the REP and its evolution. From the analysis it is clear that the system's resilience has been planned as an installed capacity issue. This has led to overinstallation during certain periods, which in turn has produced electricity price increases for the consumer in subsequent periods. Twenty-five years later, the idea of a market-based system able to increase reliability with price efficiency and long-term planning is still in development.

Part of the problem is that the agents chose to follow certain aspects of the principles of Laws 142 and 143 of 1994 but didn't have the incentives to track others, such as energy efficiency and diversification of the matrix. Part of the explanation could come from the way the REP has been used as a planning tool, focusing only on midterm expected demand achieved by generation and grid expansion, and not creating links with the National Energy Plan. We believe that the REP has lacked an appropriate follow-up strategy for expanding the national electrical system; it seems as if each REP was a midterm plan all on its own, hence there seems to be a significant delay in detecting alerts, and between recommendations to improve performance and action. There seems to be no alignment with the original recommendations stated in the first REP and adopted under Law 143.

The very philosophy of the REP as an iterative process constantly updated has led by default to increased planning capacities adjusted to new technological and climate circumstances. This is a huge asset, providing flexibility that enables the rapid incorporation of new technologies, such as NCRE, into the expected midterm matrix or new variables, such as CO_2 emissions, to fulfill NDC commitments.

The latter is probably the biggest challenge the REP will face in coming years as the increased length and strength of climate variability, a result of climate change, requires better prediction tools and an adaptive capacity to avoid the unexpected. How should we improve plans under climate circumstances that can trigger unknown variables?

ENDNOTES

1. The REP focused on the period 1995–2004 rather than 1993–2002 because in responding to the electricity crisis the 1992 REP made emergency investments for 1992–95 that covered short-term demand. As a result, the revised plan concentrated on the midterm, assuming the commissioned investment to be firm electricity.
2. Since 2008, the REP has considered 15 years as its midterm-planning window; the reason for this change in time frame is unknown.
3. As a reference point, according to EUROSTAT (2018), during the period between 2004 and 2016 the European Union increased renewable energy participation by 15% with aggressive support of new technologies.
4. XM is a company specialized in operating and monitoring real-time systems.
5. The Interconnected System is composed of the national electrical system, which is concerned mainly with large-scale generation, and the national transmission system, concerned with power lines and (more recently) the distribution system.
6. "El Niño and the Southern Oscillation, also known as ENSO, is a periodic fluctuation in sea surface temperature (El Niño) and the air pressure of the overlying atmosphere (Southern Oscillation) across the equatorial Pacific Ocean. El Niño is so termed because it generally reaches full strength toward the end of the year, and early Christian inhabitants of western equatorial South America equated the warm water current and the resulting impacts with their holiday celebrating the birth of Jesus (known as El Niño in Spanish)" (NOAA 2018).
7. The law by which the government promotes and regulates the integration of nonconventional renewable energies into the national electrical grid.

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ABOUT THE LONG-TERM STRATEGIES PROJECT

World Resources Institute and the United Nations Development Programme, working closely with UN Climate Change, are developing a set of resources to help policymakers integrate long-term climate strategies into national policy making.

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