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Scenario analysis for strategy design: A case study of the Colombian electricity industry

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ABSTRACT

The technology transformation of the power industry is crucial for electricity companies, which need to be prepared for the transition of their traditional business. Using scenario-planning exercises, combined with SWOT and PESTEL analysis, as well as a systems thinking approach, this paper explores potential strategies for electricity companies to grasp the opportunities and offset threats, by focusing on the formulation process for a broad, innovative strategy for the transition in the power business. The paper concludes that the transformation of the Colombian energy industry poses serious challenges to electricity companies when policy and regulation promote the adoption of non-conventional energy sources, at a time when the cost of renewables keep declining; however, with a robust adaptive strategy, companies could better face the transition from current business to new alternatives.

1. Introduction

Power generation from renewable sources is one of the most important technological changes in recent decades. It has resulted from concerns about global warming, rising energy demand in the developing world, and uncertainties regarding fossil fuel prices. From the 1990s to 2011, the use of energy from renewable sources has increased at an average of nearly 2%/yr [1] but what is more impressive is the rate of penetration in the last five years; this rate has increased to about 7%/yr. As a result, the total contribution of renewable energy has increased from around 1000 GW in 2007 to about 2195 GW in 2017, more than doubling in a decade, and now accounts for 26.5% of world power generation capacity [2]. Most of this renewable energy comes from large-scale hydropower (about 1114 GW, 51% of the total), wind power (about 539 GW, 24% of the total) and solar PV (about 402 GW, 18% of the total), while other renewable technologies provided 140 GW, 7% of the total.

The technological change is crucial for electricity companies and their traditional strategies, since the expansion of renewable energy threatens their traditional business models. A number of factors, including increased competition, unstable regulatory frameworks, sustainable competitive advantage, as well as rapid technological changes, are profoundly affecting electricity companies and undermining their longevity [3]. On the one hand, in the last ten years some major thermal generators have shown dramatic losses in share price, including RWE (−67.23%), E.ON (−70.29%), CEZ (−49.14%) in Europe, and Vistra Energy (−22.61%) in the United States. On the other hand, companies that generate energy from renewable sources have increased their share price, e.g. IBERDROLA (+29.5%), ENEL (+13.04%) and Xcel Energy (+94.64%) [4]. Utilities, which for most of their existence hardly engaged with customers, are now forced to reinvent themselves and adapt to a technological revolution in home energy services, installing smart technology and advising customers on how to reduce their bills. In this sense, strategic decision makers in electricity companies could benefit from '*futures techniques*' [5], such as scenario analysis [6] to gain insights into what the future might look like to adapt to this technological transformation.

Scenario planning is a form of exploration that can be adopted to show plausible futures, but it is neither forecasting nor prediction, the two widely-employed tools in traditional electricity companies.

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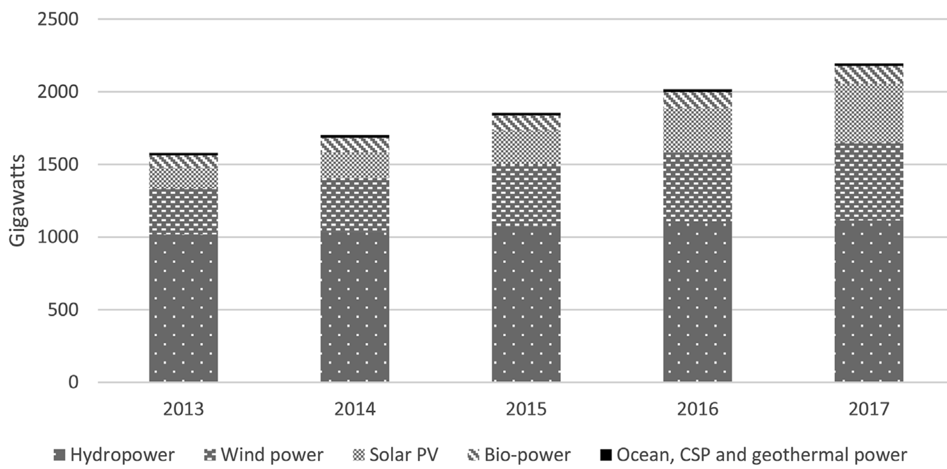

Fig. 1. Global Renewable Power Capacity, 2013–2017. Source: self-construction based on REN21 [2].

Scenario analysis can help decision-makers to face uncertainty by supplying them with various possibilities for future development [7]. A scenario describes a set of plausible future events, and their causes and consequences. Scenario analysis develops a set of structurally different situations to embrace the major uncertainties in the future business environment [8,9]. Harries [10] notes that one of the major tenets of scenario planning is that it is a useful basis for testing the robustness of plans of action, as organizations need to know when to act and, as importantly, when not to act [11].

Some examples of successful application of scenario analysis in the energy sector include transmission and distribution technology planning for the Pacific Gas & Electric Company, preparing for potential Californian earthquakes [12], and Shell preparing to deal with high natural-gas prices in the 1970s [8]. A variety of authors have generated different energy scenarios for companies and countries all around the world, as discussed in the next section.

In this changing context, electricity companies might be required to engage in properly divesting their traditional business and establishing new ones. In that sense, three main questions are posed: 1. What are the scenarios in which the electricity companies could be highly impacted? 2. What are the threats and what are the potential opportunities? 3. What could be a robust adaptive strategy to move away from traditional business while establishing new business?

The Colombian power industry, the focus of this paper, has gone through important changes since its market liberalization in 1994. In this context, the *Mining and Energy Planning Unit* (with the acronym UPME in Spanish) constructed scenarios for the energy industry in the year 2000, e.g. Ref. [13]. Some of the authors of this paper have contributed to studies using scenarios in collaboration with several of Colombia's leading electricity companies, such as ISA, ISAGEN, EPM, CELSIA, and ENDESA. As previously discussed, scenario analysis has been implemented in the energy industry as a whole and also by electricity companies. In this paper the unit of analysis is the electricity business, focusing on a simplified and innovative process for the construction of electricity scenarios and strategies for electricity companies to better adapt to this energy-technology transformation.

The main article contribution is about the process of building a robust adaptive strategy using scenarios within a systems thinking framework. This strategy will help in the transition from current electricity business which, although declining, offers profitable downsizing opportunities that can be seized with existing resources and the development of new capabilities and innovation from current business to new ones. Technological transformation brings opportunities for new businesses, but these opportunities are discussed in a sister paper [14]. This article is structured as follows: the next section shows the literature review that has been undertaken. Section 3 discusses the proposed methodology and describes the workshops that need to be implemented, followed by a section that shows likely results from this strategic planning exercise. Section 5 presents a discussion of results, and the final section concludes the paper.

2. Literature review

The literature review is organized as follows: the first section examines the technological transformation of the power industry and the uncertainties that it brings; the second and third sections discuss how scenario planning and its different approaches may help to deal with uncertainties; and, finally, reviews applications of scenario planning in the context of the energy industry.

2.1. Technological transformation of the power industry

Power systems around the world have begun a process of profound transformation, driven by the emergence of new technologies and the growing concerns for local and global environmental stewardship [15]. This transformation is influenced both by the search for means to reduce greenhouse gas (GHG) and by increasing energy demand, especially in developing countries, while also aiming to achieve efficient energy use.

Technological change has often been advanced as a desirable and feasible means by which industrialized societies can transition to low-carbon economies [16–18], avoiding 1.5 °C warming and eliminating the 4–7 million worldwide premature air pollution deaths occurring annually [19]. Technological measures include switching fuels (e.g. from coal to natural gas), adopting renewable energy sources, installing carbon capture and storage systems, and changing to higher-efficiency energy conversion technologies [20].

The introduction of new technologies leads to changes in the energy mix, alongside other drivers such as relative prices and costs, policies to promote energy efficiency, use of renewables and other new technologies, and broader market trends regarding economic efficiency and better use of resources [21]. Fig. 1 shows that in 2017 renewables capacity had its largest worldwide increase in five years, and this amounted 178 GW. Moreover, new solar PV capacity additions exceeded that of fossil fuels and nuclear power combined [22], accounting for nearly 55% of the renewable increase in power capacity. Wind energy contributed to more than 29% and hydropower to nearly 11% of the increase in renewable power capacity.

Furthermore, governments have begun to identify that the renewable-energy-technologies industry can promote both economic growth and international competitiveness, offering new business and employment opportunities [23]. Therefore, investment in new renewable

Table 1
Approaches for the construction of scenarios.

Model/Methodology	Author(s)	Year	Features/contributions
Future-Now	Kahn & Wiener [34]	1967	Employs reasoned judgments and intuition. Qualitative method.
Operational Research/Management Science (OR/MS)	Amara & Lipinski [35]	1983	Involves structural algorithms and math models. Quantitative method.
Procedure for the construction of scenarios	Wack [8,9].	1985	Supports scenarios under a robust structure, complemented with a numeric analysis.
Industry scenarios	Porter [36]	1985	The industry analysis allows an idea of what the world will be in the future.
Procedure for construction of scenarios	Millet & Randles [37]	1986	Intuitive and quantitative techniques relating qualitative and quantitative methods.
Analysis of scenarios for strategic planning. Construction of scenarios in three phases.	Brauers & Weber [38]	1988	Includes creative qualitative methods in the analysis phase.
Methodology for scenario construction in three phases.	The Future Group [39]	1994	Emphasizes focus on the critical points of the organization.
Methodology for scenario construction in four phases	Feldblum [40]	1995	Associates stochastic simulation with scenario testing.
Methodology for scenario construction in nine steps	Schoemaker [41]	1995	Possible review of scenarios after subsequent investigations.
General methodology of eight steps proposed by Schwartz	Schwartz [26]	1996	Procedural method to develop scenarios.
Methodology for scenario construction	Godet & Roubelat [42]	1996	Use of perspective in the design of scenarios.
Methodology for the development of scenarios	Van der Heijden [43]	1996	Structured method to develop scenarios.
General methodology of seven steps	Ratcliffe [44]	2000	Adaptable model for use in any type of organization.
Development of perspective scenarios	Neumann & Øverland [45]	2004	The scenarios may come directly from data from the past, present, or both.
General methodology of five steps	Fulton & Scearce [46]	2005	Includes the subsequent monitoring of the scenarios developed.
Theory for scenario planning based on the Dubin method	Chermack [47]	2005	Theoretical application to construct and test scenarios.
Transition Management Model	Sondeijker et al. [48].	2006	Transition model applying scenarios to management processes.
Warwick Method	O'Brien et al. [49]	2007	Suggests SWOT for assessing future opportunities and threats.
Scenario planning based on understanding the causality of events	Wright & Goodwin [50]	2009	Proposals for improving the effectiveness of scenario planning
Deutsche Bank research method	Weyrich [51]	2013	Determines most relevant factors for four different scenarios: ideal world, real world, exploitation and reverie.
Embedding real options in scenario planning: A new methodological approach	Favato & Vecciato [52]	2017	Explore how scenario planning and real options could be integrated in order to overcome limitations and enhance benefits, particularly in relation to the learning skills of organizations.

energy sources has increased from $159 billion USD in 2007 to $280 billion USD in 2017 [2], with the highest investment of $323 billion USD in 2015.

Distributed electricity generation and storage technologies will likewise create the need for new grid architectures, business models, and regulatory decision-making approaches. Smart Grid technologies and demand-response programs allow for more effective load balancing and overall system intelligence requiring dramatically different incentives and regulatory treatment in order to promote investment and ensure reliable performance [15]. This transformation in the power industry generates uncertainty for companies – about future challenges they will face – which is why scenario planning provides an appropriate tool for the strategy support.

2.2. Scenario planning

Organizations and policy makers have used a range of '*futures techniques*' to gain insights as to what the future might look like in order to make informed decisions. Pesonen et al. [24] provide a glossary of definitions for future research methods, which include forecasting, and scenario analysis.

Various institutes and companies, including the RAND Corporation, Stanford Research Institute, Shell, and others have influenced the development of scenario analysis [25]. The Royal Dutch Shell Corporation is credited with the introduction of scenario analysis in the private sector, where it was the first to perform a 'can use' scenario analysis successfully [26]. The development was introduced by Pierre Wack and Edward Newland for strategic decision-making purposes and has been used since the 1960s. Shell succeeded in a highly competitive environment by planning for a scenario involving a potential embargo by the oil-producing countries in the early 1970s, when its competitors were still using traditional forecasting methods and were caught unprepared when this scenario became a reality, in 1973 [27]. Since then, over 50% of the largest European and US companies have adopted scenario analysis to support their long-term planning.

The aim of scenario analysis is not to obtain forecasts of the future, but to highlight crucial uncertainties that may influence the strategic decisions that managers have to make [28]. Porter [29] observed that scenarios are a plot development for a play script, or for a story outline or content. Scenario analysis develops a set of structurally different scenarios to encompass the major uncertainties in the future business environment [8,9]. Through the assessment of multiple scenarios, decision-makers are strongly encouraged to expand their thinking and to overcome the false certainty of a single forecast, while increasing their readiness for the range of possibilities the future may hold [7]. Furthermore, Ringland [30] considers scenario analysis as a tool for strategic thinking, which can be integrated into strategic planning. Scenario analysis thus involves neither forecasting nor prediction, but instead is a form of exploration, which can be adopted to highlight future possibilities. As Burt et al. [31] noted, scenarios are not predictions, extrapolations, good or bad futures, or science fiction. Instead, they are purposeful stories about how the contextual environment could unfold over time, and these stories consist of the following:

a. An interpretation of current events and their propagation into plausible futures
b. A description of alternative and possible future developments and end-states in a horizon year, depending on the considered assumptions as to what might happen
c. Internally consistent accounts of how these alternative future worlds unfold.

2.3. Approaches to scenario construction

Since its inception, various methods for scenario planning have been developed [32], and they can be categorized into three major schools of thought: logical and intuitive, prospective, and probabilistic trend [33]. Table 1 shows a chronological list that summarizes some of the most influential approaches developed for the construction of scenarios.

Scenario planning is, thus, designed to be an organizational-based social-reasoning process that utilizes dialogue and conversation to share participants' perceptions of the environment and to facilitate

Table 2
Scenario analysis in the energy sector.

Author	Scenario
Sant & Dixit [53]	Analyzed, through a case study of Maharashtra state (in western India), electricity sector problems.
Smith et al. [13]	Created a set of possible scenarios for the energy sector in Colombia and thereby helped to create a better understanding of how the energy system might evolve into the future.
Kim et al. [54]	Developed scenarios with different levels of nuclear energy utilization, and discussed their effects on the electricity demand and supply situation in the Republic of Korea, in the year 2030.
Roinioti et al. [55]	Generated scenarios with an emphasis on the electricity generation system and its impact on energy and environment for the Greek energy system.
Wang et al. [56]	Studied the implications of changing energy and environmental policies in China.
Dagher. & Ruble [57]	Studied the economic and environmental impact of different scenarios for Lebanon.
Bautista [58]	This research study used the quantitative approach to analyze the present and future situation of the Venezuelan power generation sector in 2050.
Pan et al. [59]	Concluded, using scenarios, that demand-side management can effectively reduce the pressure on the supply side and reduce GHG emission for Beijing City.
Bazilian et al. [60]	Presented several 'high-level', transparent, and economy-wide scenarios for the sub-Saharan African power sector to 2030.
Kale & Pohekar [61]	Studied and analyzed the electricity demand scenario in Maharashtra State for various sectors of the economy up to the target year 2030.
Chen et al. [62]	Based on the Taiwanese Government's energy policy, they constructed the following three case scenarios: a normal scenario, the 2008 "Sustainable Energy Policy Convention" scenario, and the 2011 "New Energy Policy" scenario.
Brand & Blok [63]	Compared five studies using economic electricity supply and demand models to assess possible development pathways for the North African power systems, from the present until 2030 and 2050.
Mishra et al. [64].	Explored the potential for CO2 emission reduction, through clean coal technology in India's power sector.
Palzer & Henning [65]	Considered different scenarios for the German electricity and heat sector in which the energy demand for space heating, hot water and electricity is satisfied with100% renewable energy resources.
Blakers, Lu & Stocks [66]	An hourly energy balance analysis is presented from the Australian National Electricity Market in a 100% renewable energy scenario, in which wind and photovoltaics (PV) provides about 90% of the annual electricity demand and existing hydroelectricity and biomass provides the balance.
Barbosa et al. [67].	Analyzed and compared three different scenarios with different high voltage direct current (HVDC) transmission grid development levels (region-wide, country-wide and area-wide energy systems) and one integrated scenario for South and Central America.
Brown et al. [68].	Introduces additional, more feasibility relevant criteria, in which renewable energy scenarios fulfil for a 100% renewable-electricity system.
Cannolly et al. [69].	Presents one scenario for a 100% renewable energy system in Europe by the year 2050.
World Energy Council [70]	Built energy scenarios for 2050, with a focus on the electricity production system, exploring how these scenarios are reflected in economic and environmental terms, and with regard to energy efficiency.
International Energy Agency [71]	This outlook describes multiple future pathways for global energy through to 2040.
Zapata, S. et al. [72].	Provides a better understanding of the possible effect of 100% renewable generation on the Colombian electricity market. This paper simulates four scenarios to assess possible futures, driven by two major uncertainties: environmental policy and climate variability.

participants' interactions as they engage in the process of sense-making through theory building and storytelling [50].

2.4. Scenario planning in energy

Various authors, agencies, institutions and governments have generated different energy scenarios in order to better understand how demand and supply might behave. In 2018, the International Renewable Energy Agency (IRENA) published the report "Global energy transformation. A road map to 2050". The focus of their work sets out a path to energy system decarburization based on high energy efficiency and renewable energy. It provides evidence showing how the transition is occurring, and how the deployment of renewables is making energy supply more sustainable [50]. Table 2 shows some examples of the application of scenario analysis to energy issues, with a focus on the electricity sector.

The use of scenarios for strategy planning in the energy industry is widely used by big companies such as Shell [73], BP [74] and ExxonMovile [75], but it is mainly found in grey literature. Therefore, to our knowledge, very few papers have examined scenarios for a robust adaptive strategy within a systems thinking framework for electricity companies.

3. Methodology

As liberalization during the 90s promoted the transformation of energy markets worldwide, Colombia adopted a version of the UK electricity-market model, in 1994 [76]. This change brought not only competition in the market, but also some difficulties, particularly regarding: a) Colombia's dependency on hydroelectric power, especially during the long dry periods [77]; and b) market concentration in generation, as the four main companies control around 80% of the market.

Nowadays, the penetration of new technologies may initially reduce the vulnerability of the system as new technologies such as wind and solar complement hydro regimes [78], and this represents opportunities for electricity companies that need new strategies to compete in the market place. In this sense, scenario planning is useful for understanding plausible developments and how they could affect companies. Below, the case study of the Colombian electricity industry is described, followed by the steps taken to construct the scenarios and establish a robust strategy.

3.1. Case study: Colombian electricity industry

The Colombian electricity industry comprises an integrated collection of entities and companies performing an array of functions in energy generation, transmission, distribution, and commercialization.

Laws 142 and 143 of 1994 regulate the Colombian electricity sector; these laws were created to promote market competition, to allow the participation of private actors, and to separate market activities into four subsectors: generation, transmission, distribution, and commercialization. No generation company may have a market share greater than 25%. In the same way, a single company may not own more than 25% of the distribution activity. Transmission is treated as a natural monopoly.

The regulatory framework separates the users into two categories:

- Regulated users: industrial, commercial, and residential users whose energy demand is lower than 55 MWh/month, or power demand lower than 0.1 MW. For these users, the Regulatory Commission sets prices for electricity and gas.
- Non-regulated users: they have energy demand above 55 MWh/month, or power demand greater than 0.1 MW. In this case, sale prices are open and agreed upon between the parties.

Through Law 143 it was also established that electricity is dispatched according to merit order. In this structure, large users and distribution utilities may buy electricity directly from generators in two alternative ways: through medium-to long-term contracts, and in the short-term market (the electricity pool) [79].

By the end of 2017, the system-installed capacity in Colombia was 16,778 MW. System demand was 66,667 GWh in the same year, which was supplied by hydroelectric plants (86%), followed by thermal plants (13%), plus non-conventional renewables (1%) [80]. Yet the country has great potential for generating energy from renewable sources such as wind, solar and biomass, which have only been explored experimentally and because of this, in May 2014 the Law 1715 was issued, seeking to promote their use for electricity generation in the country.

Power supply in Colombia depends on the interconnected national grid (SIN), which extends over a third of the territory and provides coverage to 96% of the population; the other 4% is supplied by the non-interconnected zones (ZNI) [80], where it is not feasible to connect users to the SIN because of their locations, as they are found in remote regions, on islands, archipelagos, and small towns in the rain forest. For these areas, electricity is mostly generated by diesel plants and occasionally by hybrid systems of wind facilities, solar panels and small hydroelectric units.

The case is based on the electricity industry in Colombia, as explained before, using the experience of a number of companies, and involved working with practitioners from different departments of the companies, such as planning, generation, distribution, commercialization, marketing, R&D, and regulation. On such occasions, the participants, all of them with many years of relevant work experience, considered future strategies for their electricity companies. Indeed, this paper suggests the use of scenarios described in the case is a 'real world' practice-based strategy design exercise, in terms of the background, knowledge, and experience of the participants, and their commitment to produce a robust set of strategic recommendations for their own organization for presentation to their top management, at the end of the exercise.

The case study approach is appropriate when the phenomenon under study is not readily distinguishable from its context [81]. The phenomenon under study in this case is the strategic situation of large companies within the Colombian electricity industry, in order to assist them to adapt to energy-technology transformation. Thus, a scenario-based strategy is designed with a group of experts from different departments of the companies who may best contribute to the construction of strategic guidelines for each organization. The case study research provides freshness in perspective to an already researched topic [82] such as strategy.

In the application of a case study, it is assumed that a particular subject is studied using approaches such as personal observation [83]; for this study, a few of the members of the research team were incorporated in the groups undertaking the exercise, and made reports about the process that the group had followed.

The research involved consulting large Colombian companies. As they are confronting technological transformation, their strategic intent has two aspects: 1) protection of the traditional business, and 2) creation of new business activities; the exercise took place over a period of about four months. Because of the methodology focus here, this paper reports on the first aspect.

The leading team incorporated consultants, analysts, and assistants who developed materials required for the exercise. Part of the team had important experience of developing and using scenarios in the electricity industry. The workshop began with presentations by international and national experts on the industry, in order to provide a context for the changes in the electricity industry. The structure of the exercise and its materials were developed in consultation with senior executives from the electricity companies.

3.2. Workshop description

The exercise usually takes place across three to four meetings (depending on the specific project and the involvement of the electricity company) of around 8–12 h each. There were about 25 participants from different strategic units of the companies, including: planning (5), generation (5), distribution (4), commercialization (3), marketing (3), R&D (2), and regulation (3). Consultants, analysts, and assistants compiled the subsequent evaluation and preparation of the material obtained from each meeting by the Working Team (WT).

This exercise was designed to build different scenarios regarding the use and development of new technologies that the country might confront in the next fifteen years (2030). Through the development of the exercise, the WT established: i) a classification of identified forces, ii) three major driving forces for the underlying problem, iii) the determination of a possible road map of alternative scenarios facing the year 2030, iv) viable configurations of the Colombian energy matrix by 2030, and v) a formulated robust strategy.

- *Classification of identified forces*

In this part of the exercise, the variables were classified depending on their degree of uncertainty and the impact they could have on the sector, and a system diagram was constructed to relate variables that have greater impact when analyzing the problem posed.

The WT identified the current driving forces using PESTEL analysis, which is a tool to track the environment of the companies. It considers six different interdependent influences: Political, Economic, Social, Technological, Environmental and Legal. It is important to note that this type of analysis is an environmental analysis, usually performed in order to represent the characteristics of the electricity companies in a particular country [84].

- *Identification of major driving forces*

This step was conducted by taking account of the relevant trends in the development of the electricity industry, in the face of technological transformation processes in Colombia. Methodologically, the exercise identified three major forces driving changes in the industry. Based on these driving forces, the WT developed stories/narratives for each of the six scenarios that were considered (two were discarded because they were not relevant to the exercise). Subsequently, the stories of what will happen in each scenario can unfold.

- *Scenario writing*

The aim in this part of the methodology was to outline, and then write in full, the different scenarios that resulted from the initial identification of the driving forces. For each pair of the major driving forces, as they were located on two axes, the other forces in place characterize the particular scenario. According to Wright and Goodwin [50] the development of the storylines could, in practice, also utilize other uncertainties and pre-determined elements that had been generated by scenario workshop participants but which were seen by these participants as having less impact on the focal issue of concern.

- *Construction of SWOT matrix*

In this next part of the methodology, the WT, after helping to visualize the future environment, developed a set of strategic alternatives through a SWOT (Strengths, Weaknesses, Opportunities, and Threats) matrix. O'Brien et al. [49] suggest use of the SWOT framework for organizing an assessment of future opportunities and threats that emerge from an analysis of the future external environment (using scenario planning) with an assessment of the strengths and weaknesses of current resources and competencies [46].

– Strategies and actions (Weakness/Opportunity): aim to overcome weaknesses by tapping potential opportunities for achieving positive results in the long run.
– Strategies and actions (Weakness/Threat): must develop plans to overcome weaknesses that are amplified by threats to the companies from the environment. These actions should be adequately and accurately analyzed, as they represent weaknesses that generate risks to the success of the proposed targets.
– Strategies and actions (Strength/Opportunity): In this set of actions, the leading plans should draw upon every internal strength that can be paired with any opportunities to ensure success.
– Strategies and actions (Strength/Threat): every strength should overcome threats coming from the environment that risk the success in achieving the set goals. These actions have very high priority, so they must be well-researched and detailed.

- *Development of a robust strategy guideline*

Finally, the SWOT analysis facilitates the selection of a robust strategy and the actions resulting from the scenarios. This robust strategy is acceptable and applicable to all future scenarios, and meets the highest expectations in any scenario.

To summarize, Fig. 2 shows a brief illustration of the exercise developed in the workshop.

The identification of major driving forces and their classification were completed during the first meeting. The third part, writing of scenarios, was completed in the second meeting with support from the WT. In the third meeting, the participants constructed the SWOT matrix. Finally, in the last meeting, the group developed a robust strategy guideline. Depending on time and resources, with support from the WT, the last two workshops could have been integrated into a single workshop.

4. Results

4.1. Identification of major driving forces

In different groups, people identified variables as trends and uncertainties, and stakeholders that together impact the business structure in the medium and long term, under conditions of technological transformation such as have been taking place in the electricity industry in recent years. The different groups found, in total, approximately 50–70 trends, counting uncertain as well as certain trends.

At the end of the workshop, in a plenary session, the key factors or variables were agreed and grouped as shown in Table 3.

Subsequently, the variables were classified by the teams according to their degree of uncertainty and their impact on the "system" as indicated in Fig. 3.

After the identification and classification of variables, for all pairwise combinations of uncertain trends having both high impact and high uncertainty (hence the omission of item 12) the causal relationships between them were identified. Each variable was evaluated between 0 (no impact) and 3 (high impact), and all scores were added, as may be observed in Table 4.

At the end, the major driving forces that obtained the highest values were those numbered 11 and 19, namely "Costs of technology" and "Policy and regulation of the energy sector". These critical variables were used to construct the scenarios. Regarding the Costs of technology, this variable refers to the non-conventional energy sources' technologies, especially those for renewables. Regarding policy and regulation of the energy sector, this critical variable deals with the uncertain effects of domestic laws, regulations, and rules that promote the adoption of new energy technologies. The driving forces are dynamically reflected in the causal diagram, Fig. 4. Cycles C1 and C2 represent the market dynamics driven by the electricity price, which contributes to the adoption of renewables that feeds back into the market by reducing electricity demand, closing cycle C3. Cycle C4 represents the learning curve that drives down technology costs. The first three cycles are balancing loops with delays. In these cycles, electricity price from the grid is the driving force that promotes, simultaneously, new capacity investments in traditional technology, the adoption of renewables, and the contraction of demand via efficiency. The controlling variable is system margin. The fourth cycle, C4, is a reinforcing loop that drives progress along the local technology learning curves of renewables, which reduces the cost of the technology, further promoting the adoption of renewables.

Electricity companies are embedded within these dynamics, and thus the scenarios incorporate such dynamics.

4.2. Development of the scenarios

Using the two major driving forces previously identified, combined with the rest of the variables and the support of the PESTEL (Political, Economic, Social, Technological, Environmental, and Legal) analysis, the four scenarios were constructed as shown in Fig. 5.

The broad guidelines associated with the scenarios are briefly described as follows:

Scenario 1: Policies promote renewables and largely restrict the development of traditional generation projects. However, the penetration of non-conventional technologies is not very strong, as prices and installation costs are high. Thus, this scenario has been identified as complicated for electricity companies, but they could continue with their traditional business.

Scenario 2: Energy policy and regulation for fostering green technologies is strong and has given clear guidelines for strengthening the energy matrix using non-conventional energy sources. The penetration of renewables in the power sector is very high in the country by 2030, as the costs of renewables become very low as compared with other technologies. This scenario has been identified as one of the most beneficial scenarios for users, but is one of the most complicated for incumbent utilities.

Scenario 3: The energy policy and regulation do not favor non-conventional technologies, but promote generation from traditional sources. Costs of technology are competitive, supporting the installation of projects in non-interconnected zones. This scenario does not represent a major threat to the traditional business of the electricity companies.

Scenario 4: The absence of clear policies, difficulties in adopting green technologies, and the absence of signs for new business have all affected the investment needed to increase the installed generating capacity. The commercial potential for exploiting green technologies failed because of high costs of adoption and installation in the country. Hence, this scenario has been identified as one of the most favourable

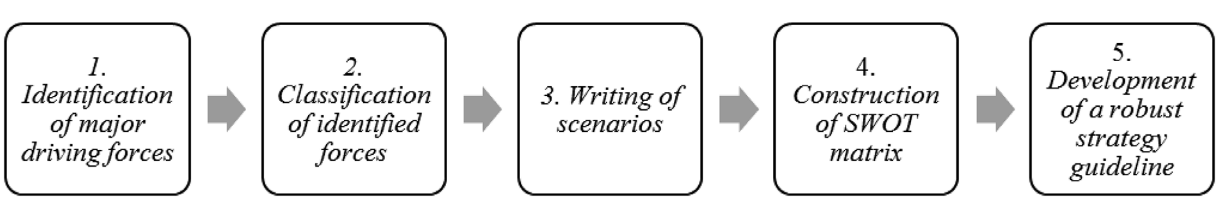

Fig. 2. Scenario analysis process as applied in this paper.

Table 3
Scenario analysis in the energy sector.

Trends – Variables	Uncertainties – Variables
1. Availability of technologies for different energy sources	11. Costs of technology
2. Risk aversion of the State	12. Regional energy integration
3. Stable macroeconomic conditions	13. Commodity prices
4. Social and environmental pressure for technological change	14. Demand participation as a supplier
5. Availability of financial resources	15. Technology adoption capacity in the country
6. Cost and efficiency of traditional technologies	16. New sources of gas supply for the country
7. Availability of energy resources (hydro power & fossil fuels)	17. Uncertainty in the energy matrix by 2025
8. Demand increases	18. Dominant technology in the transport sector
9. Evolution of energy technology	19. Policy and regulation of the energy sector
10. Distributed generation (DG) and smart grids	20. Technological development in energy storage (batteries)

scenarios for the existing electricity companies as their traditional business is not affected.

Scenarios 1 and 4 are theoretical since costs of renewables, especially Solar PV are low, and costs will further decline. However, we report them here as part of the results from the exercise with the WT.

Fig. 6 shows the energy matrix for Colombia by 2030 under the different scenarios, based on these general assumptions:

- Demand projections of UPME – Review April 2018 (90,514 GWh in 2030) [85].
- Document 077 (2014) limits the growth of Small Hydropower Plants –SHP
- Transmission lines limit the deployment of wind energy
- Reference expansion plan for generation - transmission 2017–2031 [86].
- Analysis of the optimal power system expansion for Colombia until 2030 [87].

4.3. Robust strategy

According to O'Brien and Meadows [88] one of the common principles of scenario use is that a strategy, or a set of strategies, should be robust or resilient across scenarios. However, the proposed route to this set of strategies appears to vary, with some authors suggesting the use of a 'planning-focus' scenario from which to develop an initial set of strategic options.

The scenarios constructed in the previous section are used as the background against which a robust strategy will be formulated. Initially, a SWOT analysis is conducted for each scenario and the corresponding strategic elements for each of them are determined, in case that future scenario occurs. However, as any one of the four scenarios might occur, a robust strategy will be one that works in all cases. This paper proposes a process for constructing a robust strategy based on the worst-case scenario for companies, and includes strategic elements from the remaining scenarios so that these will work for all likely futures. This is a circular process that validates the robustness of the strategic intent. Strategic adjustments may be conducted, depending on how the future will unfold. Table 5 shows the elements of the SWOT analysis identified in the plenary session.

In the context of technological power transformation, as the electricity company strategy will seek to maintain the company's leadership in its traditional business in Colombia by the year of 2030, a series of actions should be undertaken. To achieve this, the electricity company should develop entrepreneurial skills, including the establishment of

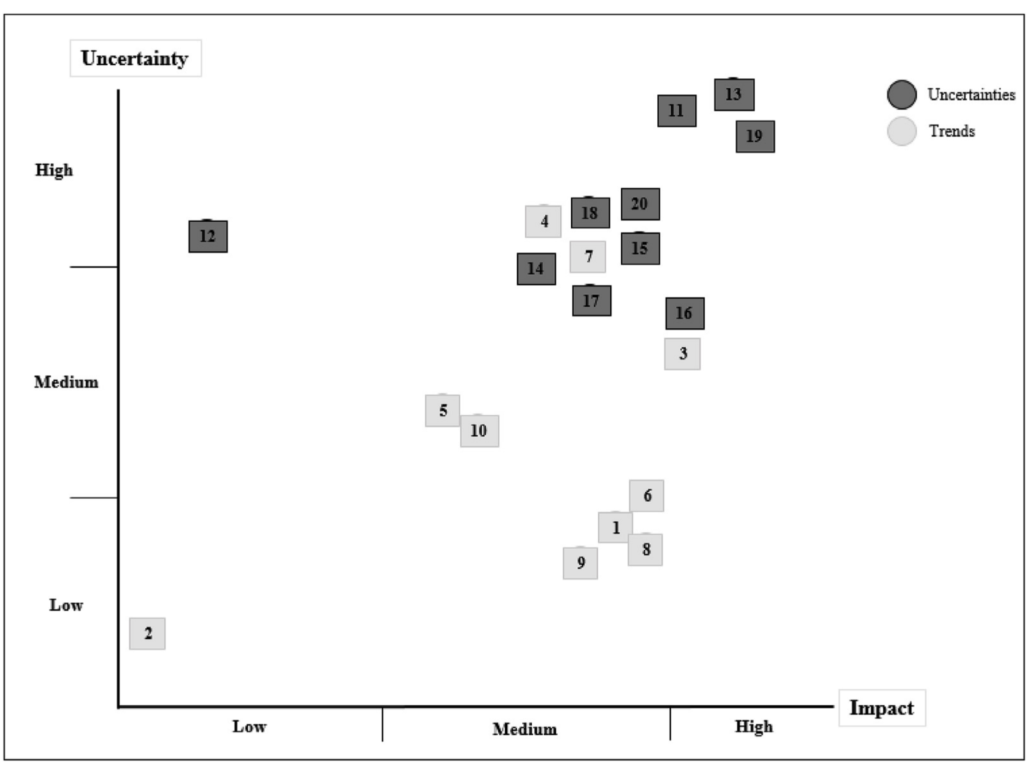

Fig. 3. Classification of variables.

Table 4
Cross impact matrix. Relationships between uncertainties.

		Uncertainties – Variables									Total
		11	13	14	15	16	17	18	19	20	
11	Costs of technology		3	2	2	1	3	0	2	3	**16**
13	Commodity prices	2		3	1	2	3	0	2	2	15
14	Demand participation as a supplier	2	2		1	2	0	0	3	2	12
15	Technology adoption capacity in the country	3	2	1		0	0	0	1	2	9
16	New sources of gas supply for the country	2	3	3	2		0	0	3	2	15
17	Uncertainty in the energy matrix by 2025	1	1	1	1	2		0	0	2	8
18	Dominant technology in transport sector	1	0	0	1	1	1		1	0	5
19	Policy and regulation of the energy sector	3	2	3	3	2	2	0		3	**18**
20	Technological development in energy storage (batteries)	2	3	2	0	0	0	2	0		9

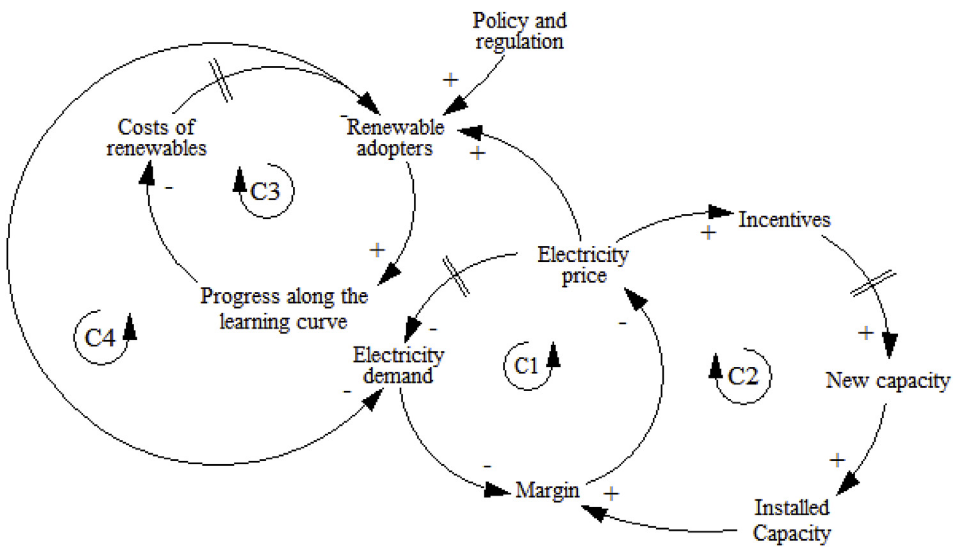

Fig. 4. Causal diagram of market dynamics.

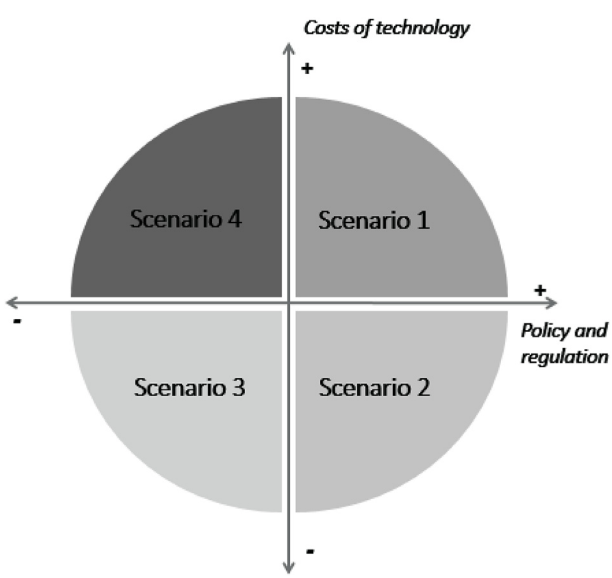

Fig. 5. Scenarios.

indicators necessary for measuring, monitoring, and ensuring the compliance of goals, in terms of growth and efficiency management, while preserving reputation. The company requires the incorporation of risk management guidelines for individual projects and a better understanding of financial risk.

One important element of its strategy is increasing investment in R&D to make better use of current infrastructure and to seek alternative applications of current technologies, evaluating the competitiveness, reliability, and the impact (environmental and economic) of the use of non-conventional energy sources. Another is to develop prototypes and acquire knowledge of technologies that improve efficiency, leading to the implementation of new electricity-generation systems. Skills for better use of current infrastructure should be developed, as well as making use of current skills to develop further skills, for example in closely associated projects such as those for building wind farms.

A further strategic element would be to develop projects and seek opportunities in: demand participation (including DG and smart grids), non-interconnected areas, and efficiency initiatives. It could be beneficial to activate the interaction between institutions, and start joint actions to support and improve the regulatory framework.

In summary, the robust strategy that focuses on the protection of the current business includes the following elements: development of entrepreneurial skills and efficiency management, development of R&D skills for better and alternative use of current infrastructure and technology, and active monitoring of the transformation of technology and energy industry regulation.

5. Discussion

The exercise was designed to find a common view on possible alternative future development strategies that can help electricity companies adapt in the face of different options identified in scenarios of technological transformation in the electricity sector. In this sense, it was important to understand the dynamics of these technologies and the potential for the companies, with special attention to the dynamics

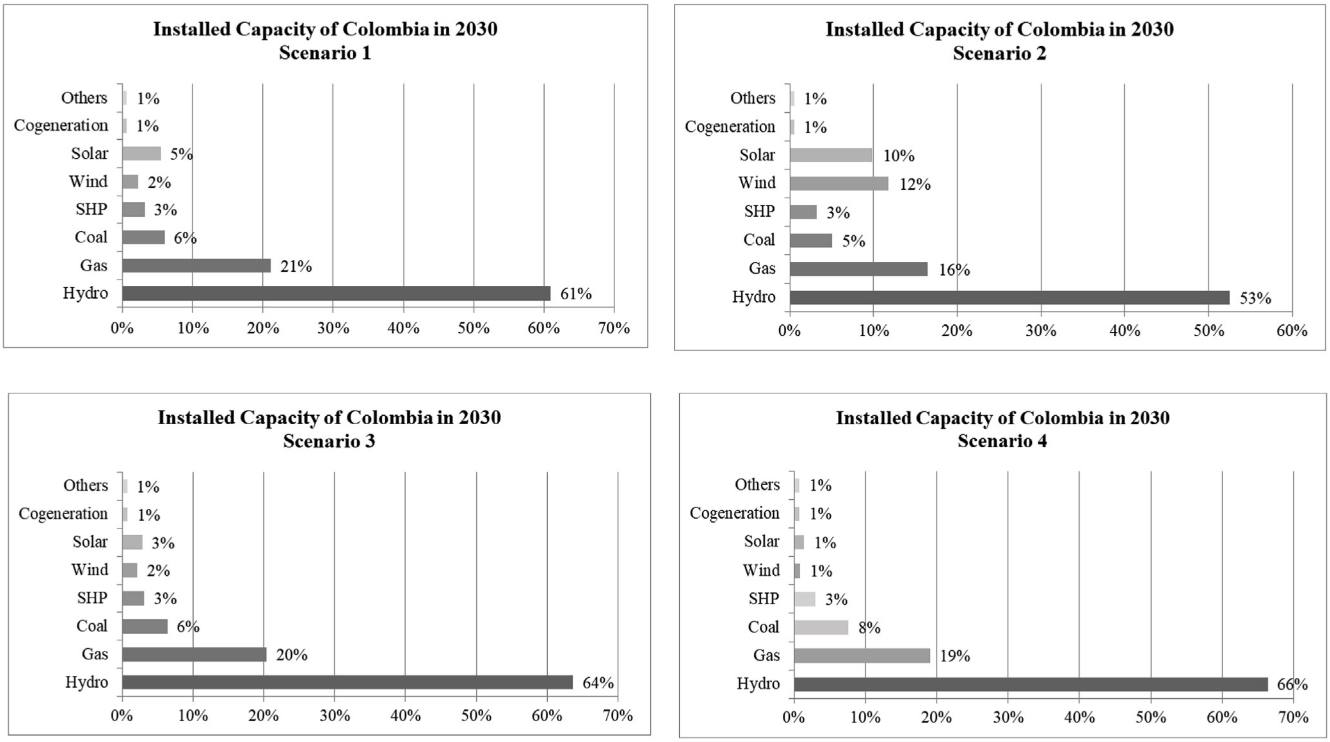

Fig. 6. Colombia's installed capacity in 2030, for the four scenarios.

Table 5
SWOT analysis.

Weaknesses	Strengths
1. Low level of enterprise	1. Profound knowledge on non-conventional (hydro and thermal) technologies
2. Slow decision-making processes	2. Market reputation
3. High risk-aversion	3. Technical capacity
4. No knowledge of new technology	4. Good reputation with government
5. Little investment in R&D	5. Human resources
Opportunities	Threats
1. New business lines	1. Reduction in revenues
2. Capture new customers (in different sectors and regions)	2. Customers adopting renewables
3. Distributed generation and smart grids	3. New competitors
4. Participation in non-interconnected zones	4. Pressure for lower electricity prices
5. Energy efficiency	5. Customer pressure for clean energy

that, over the time horizon of the exercise, might lead to the development of different power-generation technologies.

The construction of scenarios gave a clearer picture of what circumstances the country could face as a result of the technological transformation in the coming years. Additionally, the exercise contributed to the identification of common paths to facilitate dialogues and agreements among the different participants (people from different departments in each company) and perform common actions toward the best potential strategy. This implied a need to propose possible future market situations, analyzing for each the results that could be obtained with the proposed strategy.

The next sections reflect on the approach that has been proposed, from two questions: how effective the methodology was? And, what the limitations of the study were?

5.1. Assessment of the methodology

The challenge of providing a methodology to consider the technological transformation of an economic sector is to find a means of analysis that is 'tractable'; this means that it can be completed within a reasonable time, but is still sufficiently comprehensive. A sector such as electricity is sufficiently complex to be, overall, beyond the full understanding of an individual, so a 'comprehensive' view depends on collaboration among the participants of different business units. Broadly, the approach offered here appears to be a sensible solution. The experience with this case study showed the use of SWOT and PESTEL analysis to be a useful tool to assist in this process. As SWOT and PESTEL analysis have limitations: the first is static and the second mainly considers tendencies, the methodology proposed here combines them with scenario planning and causal diagrams in order to better understand the dynamics of the variables involved. While future opportunities and threats for the organization are captured by considering explicit key features of the possible future environments, through an assessment of current resources and capabilities it was possible to establish their internal strengths and weaknesses.

Comparing this study with a previous one from 2005, namely "Energy scenarios for Colombia: process and content" [13], where the aim was:

(…) to create a set of possible scenarios for the energy sector in Colombia and thereby help to create a better understanding of how the energy system might evolve into the future. The energy scenarios for Colombia seek to define possible energy futures for the country, in such a way that a wide discussion can be initiated on how the country should face, from the energy point of view, each of the envisioned outcomes. It tries to identify the main events that could affect the energy sector and to describe their consequences, based around two strategic uncertainties, which create the skeleton for the scenarios. The first one represents the way in which the Colombian conflict is resolved. The second axis concerns how Colombia will integrate into the globalization process now taking place worldwide.

We can observe a significant difference. In the 2005 study, the authors constructed scenarios for the energy market in Colombia as a whole, which means that it included not only electricity, but also oil and gas. In this study, the WT found strategic guidelines for the electricity market alone. The major driving forces and uncertainties, and the horizon year too, are also very different, so that the resulting scenarios showed dissimilar characteristics between the two studies.

The implemented methodology takes elements from different authors, such as Schoemaker [41] and Schwartz [26], identifying the basic trends and the key uncertainties, and O'Brien et al. [88] with the use of the SWOT tool. This mix of methods allowed us to create a step-by-step approach in line with our needs and thus construct more realistic scenarios.

The main findings from the process of building a robust strategy for electricity companies to transition from current business to new ones indicates that technological transformation in the power industry brings opportunities that can be seized with existing resources, and the development of new capabilities and innovation in current processes. Furthermore, given the embedded nature of electricity companies, systems thinking is needed when the driving forces have different dynamics.

5.2. Limitations of the study

There are two potential limitations of the case study results:

(1) The working team consisted of different members of the company. Even though there is the advantage of different points of view, in some cases there may also be disadvantages in the conservative view of the business. Additional issues might be generated by the lack of understanding of the dynamic complexity inherent in an industry experiencing continuous transformation [89].
(2) Changes in technologies and the business environment greatly affected the scenarios. In particular, energy technologies and the business environment have experienced, and will continue to experience, important changes due to the rapid advances in science [90], the volatile political forces in the international energy scene [91], as well as the effects of the learning curves of technologies (e.g., the price of solar PV modules per watt has fallen from 2.5 $/w in 2009 to $0.27-$0.37/w range in 2018) [91].With limited resources, the case study has the disadvantage of not being able to be as comprehensive and timely as might otherwise be possible in incorporating all these uncertainties in the technology transformation process.

6. Conclusion

This paper uses scenarios to support strategic development for electricity companies in the Colombian electricity industry facing technological transformation. We began with a review of the literature describing the use of scenarios, especially in the energy sector and focused on electricity, and on the technological transformations in the sector. We then presented the case study of Colombia, based on the experiences of a number of power companies, describing the scenario planning process used for supporting strategy design within the context of technological transformation in energy. While the case has some limitations, we believe the most important contributions are a clear description of the systematic process of scenario analysis, a detailed demonstration of its application through a case study on the technological transformation in energy, and the valuable results and insights gained from the application that could perhaps be extrapolated to other contexts.

From the perspective of the transformations in the electricity industry, this paper provides a view on those scenarios in which companies could be strongly affected and that are impacted when the cost of technology adoption is low, and policy and regulation are favourable to the promotion of non-conventional energy sources. The most advantageous and challenging scenario for electricity companies is where the cost of renewables keep decreasing and policy and regulation are favourable to the new technologies, so they have to downsize their traditional business and seek new opportunities. Electricity companies have to move and adapt to technological progress, if they do not want to risk getting squeezed out of the market.

From the method, this study shows that the use of scenario planning is a useful tool to put forward strategies to enable the electricity companies to seize the opportunities and offset the threats presented by the uncertain changes in technologies and the business environment. The robust strategy focuses on transforming the current business with existing resources and the development of new capabilities. The process to construct the strategy required systems thinking, as the scenarios present a variety of different dynamics that have to be considered and compared. Technological transformation also brings opportunities for new business; this issue is discussed in Ref. [14].

In Colombia, as in many countries around the world, technological transformation in the energy sector would have an effect on society as a whole where there is a strong institutional commitment [92]. Insights from this discussion might be useful elsewhere.

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