# Innovation Process in the Brazilian Electric Sector

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## ABSTRACT

The electrical sector is in the eve of profound modifications due to the market diffusion of several related technologies. Some drivers of this transition are: the increasing support from society for reducing carbon emissions; the growing speed of development and cost reduction of renewable energy generation technologies; new energy storage devices; new automation spread all over the network; a dramatic increase of the computational capacity; and new regulations related to energy usage.

Innovation will play a key role in the transition process of the electric sector, promoting changes and creating opportunities for new technology, products, system, regulation and business structures.

Since July 2000, law 9.991 established the Brazilian Electric Sector R&D Program that states that 1% of the income of the electric companies must be invested in R&D (research and development) projects, 40% of this overall budget stay under the electric company discretion (the Program is coordinated by the Brazilian electric sector regulatory agency, ANEEL). As a result, BRL 13.5 Billion (approximately equivalent to USD 3.5 Billion) were invested in 4,300 projects from the year 2000 until 2014. What were the results achieved by the Program? And how has it contributed (or not) to the ongoing transition process? To date, no systematic and comprehensive study has looked at the whole period of the Program.

This study introduces the first insights of a two-year research project that seeks to address these questions and to fill this gap. It presents an overview of the projects that have been carried out since 2000, and develops a unique methodology that will be used to evaluate the qualitative and quantitative historical benefits of the Program. The methodology considers four perspectives: electric companies, electric sector, academic sector and systems and services providers. It will also present scenarios that will be considered to improve the R&D Program and to inform related public policies and regulations that seek to stimulate Brazilian companies to invest in the electric sector innovation process, and ultimately contribute to the sector's transition.

## 1 INTRODUCTION

Since July 2000, law 9.991 established the Brazilian Electric Sector R&D Program, which states that 1% of the income of the electric companies must be invested in R&D projects. The aim of this work is to draw some preliminary results of this program between 2008 and 2014 as well as make introductory propositions to increase its efficiency and effectiveness. In order to do so, we will also provide a brief framework of Brazilian electric sector innovation process and its associated risks and opportunities.

Some previous research tried to measure the impacts of ANEEL R&D program (IPEA, 2008 and CGEE 2014) but for different periods. Therefore, the proposed methodology also aims to fill this gap in the literature.

It is worth highlighting that this work is part of a broader research that intends to make a deep assessment of ANEEL R&D program as well as provide regulatory alternatives based on international best practices.

In section 2 we will draw a summary of main tendencies regarding technological innovation for the electric sector. Section 3 provides a brief description of innovation process in Brazil. ANEEL R&D program is presented in detail in section 4. In section 5 we show some early results of the assessment of the program and in section 6 is presented the methodology that will be adopted in the research and development project that will be carried in the scope of the follow-up of this study. In section 7 we point out the main conclusions.

## 2 CHANGES IN ELECTRIC PARADIGM WORLDWIDE

World electric sector has been experiencing drastic changes. Environmental pressures and security of energy supply have triggered most of these fast transformations. Some aspects, such as, generated distribution, new technologies of energy generation, smart grids, technologies for efficient energy consumption, transport technologies, markedly the introduction of electric vehicles are bound to increase the complexity of the electric sector.

Technological improvements in the productive process and the increasing performance of distributed generation sources, associated to new technologies to store energy create conditions to a more decentralized generation segment, impacting heavily the traditional business.

Innovation plays a main role in the new technological paradigm that emerges, creating opportunities for several segments of the economy and establishing conditions to enhance and consolidate an Innovation Sectorial System, in order to accelerate and articulate the sectorial development agenda.

Besides distributed generation, the electric sector in the future will also face several new technologies of illumination, cooling, heating and electric cars. The development of microgrids, virtual plants aiming to approximate the energy generation and the point of consumption, and smart systems to carry and store energy will also contribute to a more decentralized sector. There is also a tendency of large-scale diffusion of sensing, controlling and communication devices, where individuals will possess equipment with high processing capacity, improving the observability within the sector. Such developments will provide important contribution to enhance performance and reduce costs.

Several authors observed this tendency and formulated analogies to explain the evolution of electric sector. The most traditional view compares the development of electric sector to what happened in the informatics industry in the 70's and 80's. The development of microcomputers that started to compete with centralized computers culminated in a destructive creation in the sector. In the electric sector, such structural changes may take a longer time to occur, given the horizon of investments and the amount required. It is reasonable to estimate that a long period of coexistence will remain until new high tech devices and machinery replace the technologies of the past. In allusion to the telecommunication sector, and the fast development of mobile phones and smart phones, it is important to call attention to the fact that distributed generation can origin new business models that could redefine the sector, mostly in distribution segment.

In this new configuration of the electric sector driven by key innovations, it is expected that consumers will have a more proactive role regarding energy generation and consumption (Prosumers). The perspective is that in following years or decades, the electric sector will develop, but the results are still unpredictable. A large number of researches on the theme has been emerging, which might also generate opportunities for innovation in the sector.

## 3 THE INNOVATION DYNAMICS IN BRAZILIAN ELECTRIC SECTOR

In face of the technological innovations that are likely to take place in the world scenario over the following years or decades, we will try to describe the tendencies for Brazilian electric sector as well as the risks and opportunities associated to such tendencies.

It is estimated that around 75% of Brazilian electricity is generated by renewable sources, mostly hydropower. As a result, Brazil has one of the world cleanest energy matrices. The main hydro resources are localized in Amazon region, highly sensitive in terms of socio-environmental impacts and geographically distant from high consumption areas. This fact tends to increase transmission costs, since lengthy transmission lines will be required to connect these plants to the centralized system.

Brazil presents comparative advantages regarding non-conventional renewable energy sources given climate, natural conditions and economic activities. Most of this potential comes from the abundance of winds and solar irradiation during the whole year. Biomass from sugar cane and forestry activities can also be largely exploited.

Wind energy has been increasingly introduced in the system. It is expected that this source will be responsible for 11.6% of generation capacity in 2024, which represents an accumulated growth of 213%. The main challenges associated to wind expansion currently derive from its intermittence and the necessity to readapt the transmission system to meet the decentralized aspect of this technology.

The development of solar energy will occur through solar auctions and distributed generation. Regarding distributed generation (DG), the high capital cost, associated with low regulatory incentives (net metering scheme with no commercial transactions) create obstacles to the dissemination of DG systems in Brazil. On the other hand the high end user tariff has already created the grid parity conditions. The main issues remain in the financial mechanism to decrease the end user capital investment. It is expected a high diffusion of solar energy in Brazil in the out coming years.

Biomass has been increasingly applied in industrial self-production of energy and cogeneration, and technological innovation must play an essential role to intensify the use of this source.

In the transmission area the ten years Brazilian plan (PDE 2024) presents an increase of the transmission capacity of 60% compared to the current capacity. Due to distance between the power plant sites and the energy consumption centers it is expected the implementation of several large voltage AC and DC lines in Brazil.

In the Distribution segment, the main driver will be the implementation of smart grids in several companies to improve the quality of its services and reduce the non-technical losses.

In Brazil, equipment suppliers play an important role in the innovation process since they are traditionally the main drivers of new technologies in the electrical sector. Such suppliers are usually transnational companies with large participation in Brazilian economy, such as GE, Siemens, ABB, Areva and Alstom. Therefore, we can conclude that innovation process in Brazilian electric sector is strongly dependent on large suppliers.

According to Pavitt (1984), the prominence of global players coordinating the innovative process derives from the assets specificities of the economic sector. Such specificities becomes clear when we observe that after the settlement of generation, transmission, and distribution infrastructure, most of the innovation comes from equipment upgrading, which makes possible a constant gain of productivity.

Suppliers, typically large international companies, become responsible for modernization of this equipment, and they take advantage from elevated barriers to entry. Even in the installation phase of new electric infrastructures, the intensive capital expenditure necessary requires the use of equipment in the technological frontier, in order to postpone upgrades, which increases the degree of dependence of such suppliers.

The aforementioned scenario makes necessary the development of internal mechanisms to promote innovation, in order to reduce dependence of transnational companies and to create opportunities for a more integrated national industry of capital goods. A regulatory initiative that intended to address this gap came out with the law 9.991.

## 4 ANEEL R&D PROGRAM

ANEEL (Brazilian Electric Sector Regulatory Agency) Research and Development program is important not only as an initiative to reduce Brazilian dependence of global suppliers in the innovation process but also to qualify human resources and to diffuse knowledge.

Decree 2.335/97 gave ANEEL responsibility for promoting research and technological development in electric sector. The regulatory apparatus established by Law 9.991/2000 required that electric sector companies should allocate 1% of their net operating income (NOI) to programs aiming to promote innovation in the sector. Forty percent of the resources is regulated by ANEEL and managed by the companies themselves. Forty percent is directed to the Ministry of Science, Technology and Innovation and the remaining 20% goes to the Ministry of Mines and Energy. Some of the R&D areas that ANEEL suggests are energy efficiency, renewable sources, environment, quality and reliability, planning and operation of electrical systems, measurement and billing, transmission of data by electric grids, new materials and components and strategic research.

Between 2000 and 2007, the program allocated approximately BRL 3.5 Billion (USD 885 Million) in around 2,400 R&D projects. The main areas of investment in R&D during this period were strategic research (25%), energy distribution (21%) and energy generation (14%).

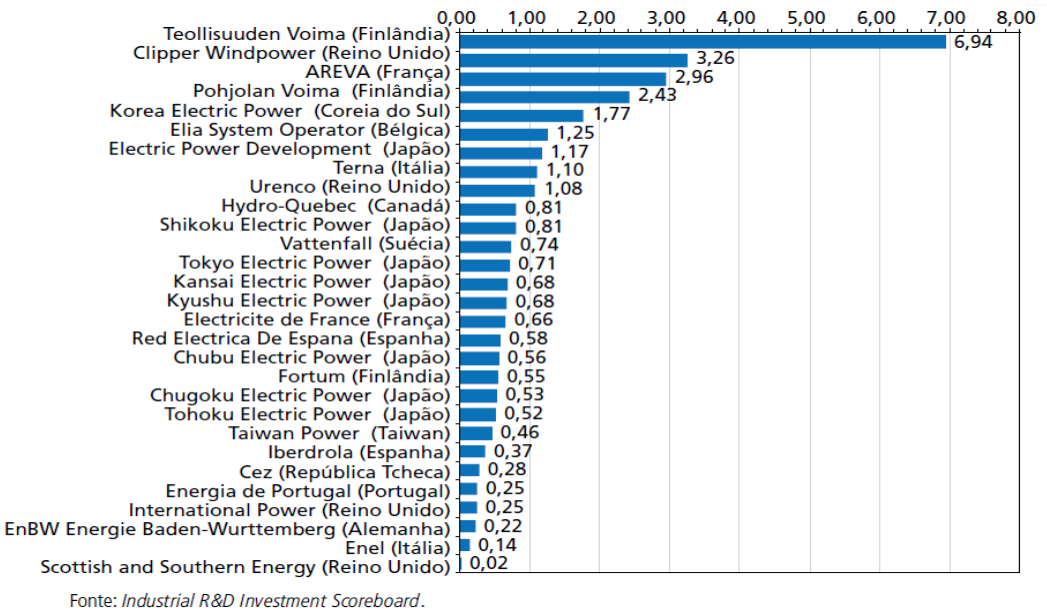
Given that the program is being conducted for 15 years, the main question that arises is “How to create an environment favorable to increase the efficiency and effectiveness of the R&D projects in order to promote innovation in national electric sector?” After 2008, several improvements were introduced in ANEEL R&D program in order to enhance efficiency and efficacy of the projects. The main change introduced was that the

investments in R&D projects started to be recognized and approved only after the assessment of the projects and verification of expenses. The effects of such modifications will be deeply studied in the scope of a R&D project with the methodology of section 6.

# 5 PRELIMINARY RESULTS AND ANALYSIS FOR THE 2008-2014 CYCLE

The current situation of investments in research and development in Brazilian electric sector is well summarized by the Industrial R&D Investment Scoreboard, which ranks several electricity companies according to the percentage of NOI invested in R&D. As you can see below:

**Figure 1 - Investment in R&D as percentage of NOI**




Fonte: *Industrial R&D Investment Scoreboard*.

Source: Industrial R&D Investment Scoreboard

In a straightforward and simple way, if we assume that all electricity companies covered by ANEEL R&D Program invest the mandatory proportion of 0.4% of its NOI in R&D activities, they all would be ranked at 23th position in average. The main proposition of ANEEL R&D program is to make electricity companies increase their investments in R&D projects in a more effective way.

Based on a report from US Energy Department, which presents the amount of investments in R&D by area from 1961-2008, we have the following results: in the period reported, USD 172 Billion was invested in R&D programs. The focus of these investments were: nuclear energy (36%), basic research and fossil sources (34%), renewable energy and energetic efficiency, that together add up 36% of total investments.

In Brazil, the particularities of the system imposed other high priority themes. Based on ANEEL public information, we can see below the amount invested in each issue:

**Table 1: Quantity and value of investments in R&D projects under ANEEL regulation, by area 2008 – 2014**

| Year | 2008 – 2011 | | 2012 | | 2013 | | 2014 | | Total | |
|---|---|---|---|---|---|---|---|---|---|---|
| Issues | Quantity | Total (Million USD) | Quantity | Total (Million USD) | Quantity | Total (Million USD) | Quantity | Total (Million USD) | Quantity | Total (Million USD) |
| Alternative sources | 70 | 83 | 40 | 135 | 11 | 23 | 17 | 30 | 138 | 271 |
| Supervision and controlling | 141 | 87 | 44 | 27 | 15 | 9 | 15 | 11 | 215 | 133 |
| Operation | 77 | 49 | 32 | 16 | 12 | 9 | 16 | 10 | 137 | 83 |
| Environment | 51 | 28 | 29 | 24 | 10 | 10 | 19 | 9 | 109 | 71 |
| Planning | 56 | 28 | 20 | 15 | 4 | 8 | 14 | 13 | 94 | 64 |
| Energy quality | 58 | 43 | 17 | 9 | 5 | 2 | 10 | 4 | 90 | 58 |
| Measurement and billing | 62 | 32 | 14 | 9 | 6 | 3 | 14 | 7 | 96 | 52 |
| River basin management | 18 | 18 | 14 | 24 | 4 | 2 | 5 | 2 | 41 | 46 |
| Security | 48 | 24 | 12 | 5 | 8 | 6 | 9 | 7 | 77 | 42 |
| Energy efficiency | 49 | 23 | 16 | 9 | 6 | 6 | 5 | 5 | 76 | 41 |
| Thermal power | 17 | 5 | 4 | 3 | 3 | 2 | 12 | 16 | 36 | 26 |
| Others | 79 | 62 | 13 | 13 | 14 | 22 | 20 | 59 | 126 | 156 |

Source: ANEEL, 2015

From table 1 we highlight the following points:

- There is high incidence of projects in areas such as alternative energy sources. This is in accordance with international tendency of research for new energy sources;

- Electricity companies made high investments in alternative sources. This fact can be explained by ANEEL calls for projects in strategic areas: solar energy, biomass and wind energy;

- There is an evident focus on projects associated to management, operation and maintenance of companies. Such projects are related to current needs that companies have in terms of improving management and the performance of its assets;

- The small amount of projects associated to energetic efficiency and thermal power calls attention to the necessity of better understanding of the strategic role that such themes have;

The analysis of public data shows that most of projects are developed individually by each company without any form of interaction with potential beneficiaries within the sector. This fact shows the need of coordination and cooperation. It clearly affects the learning process and the development of the sector as a whole. The large number of companies that are required to develop R&D projects makes this problem even more critical.

In the publicly available ANEEL's database it can be retrieved an indication of each project in the innovation chain. Table 2 below summarizes this information for projects developed from 2008 to 2014.

**Table 2: Quantity and cost of projects according to their stage in the innovation chain**

| Stage in innovation chain | Quantity | Total (Million USD) | % of total value |
|---|---|---|---|
| Basic research | 72 | 31 | 3,0 |
| Applied research | 682 | 553 | 53,0 |
| Experimental project | 368 | 384 | 36,7 |
| Head of series | 86 | 54 | 5,2 |
| First batch | 26 | 22 | 2,1 |
| Market insertion | 1 | 0 | 0,0 |
| **Total** | **1235** | **1044** | **100** |

Source: ANEEL, 2015

Differently from Frascati Manual that divides R&D activities into three categories, ANEEL expanded this number to six. They are: basic research, applied research, experimental project, head of series, first batch and market insertion.

We see from table 2 that 97% of total cost of projects is in some intermediary phase of the innovation chain. Some hypothesis can be raised from these results:

- Electricity companies can benefit directly from projects at initial stages of the innovation chain because they will be customized to its need;
- The concentration of projects at intermediary stages reduces the risk of losses in case ANEEL does not recognize part of the R&D investments made;
- Electric companies are not prepared to manage and develop basic research because such activities requires high skills and present several risks;
- Electric sector companies are not prepared and does not have commercial structure to insert their products in the market. As a result, they continue to depend strongly on suppliers and other agents.

The framework we presented above makes clear that exists a gap in the innovation cycle, since the great majority of projects were not successful in terms of introducing perceived innovation in the electric sector. Perceived innovation is the one that the entire electric sector can take advantage of.

In 2008, IPEA (Applied Economics Research Institute) launched a study in which they identified the degree of engagement of companies in the program. Their participation in most cases was limited to point out problems and check the results of projects developed by partners. Science and Technology Institutions present a closer participation in these projects.

A very important outcome of this study was the low participation of major suppliers of the sector, which also affects adversely the performance of the program. The analysis that IPEA conducted demonstrated a very low engagement of traditional suppliers in the projects assessed. It is necessary to revisit this topic through a deeper analysis for the period from 2008 to 2015 in order to suggest alternatives to engage suppliers during the project. Such initiatives would increase significantly the chances that the R&D projects generate perceived innovation for electricity companies.

The great number of projects developed and the great amount of money allocated demonstrate the success of the program. Nevertheless, there is still a need to create an environment that stimulates the innovation process in order to promote the insertion of such projects in the market.

From the analysis provided above, we can draw some initial remarks:

- A large share of the projects impact uniquely the energy companies involved directly in the R&D project;
- The majority of projects are in an intermediary stage in the innovation chain;
- An important alternative to promote evolution of R&D projects in the innovation chain is the possibility of articulation with public and private promotion agencies in order to use the resources mobilized by ANEEL R&D program that are managed by the Ministry of Science, Technology and Innovation;
- There is a necessity to create mechanisms to stimulate the participation of national and international suppliers in the R&D projects;
- Academic institutions with robust technologic capacitation must articulate and propose projects consistent with emerging and disruptive technological areas such as: energy storing, nanotechnology, chemistry, new fuels, etc. Such projects require massive investments that must be made in association with companies in the sector.

## 5. PROPOSED STUDY

The proposed study has the scope of increasing the ANEEL R&D Program and comprehends the following points:

1 – Assessment of economic and technological impacts of the Program on Brazilian electric sector (including consumers), including trends and alternatives in terms of technology, such as main technological focus, development stages, existent and potential market. The work comprehends interviews with key agents of the electric sector to assess: obstacles in formulating new projects, strategies to mitigate investments risks, strategic partnership with academic and industrial sector, expected and effective results generated by the program, barriers to commercialize technologies.

2 – Assessment of qualitative and quantitative impacts of the Program on Brazilian electric sector: Interviews with R&D managers and services and equipment providers to assess alignment of the R&D projects with the company strategic policy, capacity to disseminate an innovation culture inside the companies, establishment of new metrics to monitor and evaluate the R&D projects.

3 – Assessment of the impacts of the R&D projects in academic sector including: identification of the main academic centers, research areas and specialists involved in the projects; scientific production (patents, papers, masters and doctoral dissertations and others); investments in laboratory facilities and acquisition of equipment; training initiatives for human resources of companies. The methodology includes several technical meetings and interviews with selected professionals in order to assess qualified information, regarding: Impacts of the R&D projects in terms of raising funds for research infrastructure in the universities; Main obstacles regarding projects execution.

4 – Assessment of impacts of the projects on supply of new goods and services: evaluation of the participation of services and equipment providers in R&D projects, in order to examine the impacts of the projects on supply of new equipment and services. We will also provide an assessment of the main obstacles and propose measures in order to obtain a more efficient projects execution.

5 – Assessment of the value creation potential of the R&D program given its available resources and based on methodology of value generated by technological development modeling including the selection/prioritization of main issues and a quantitative evaluation of the potential benefits generated.

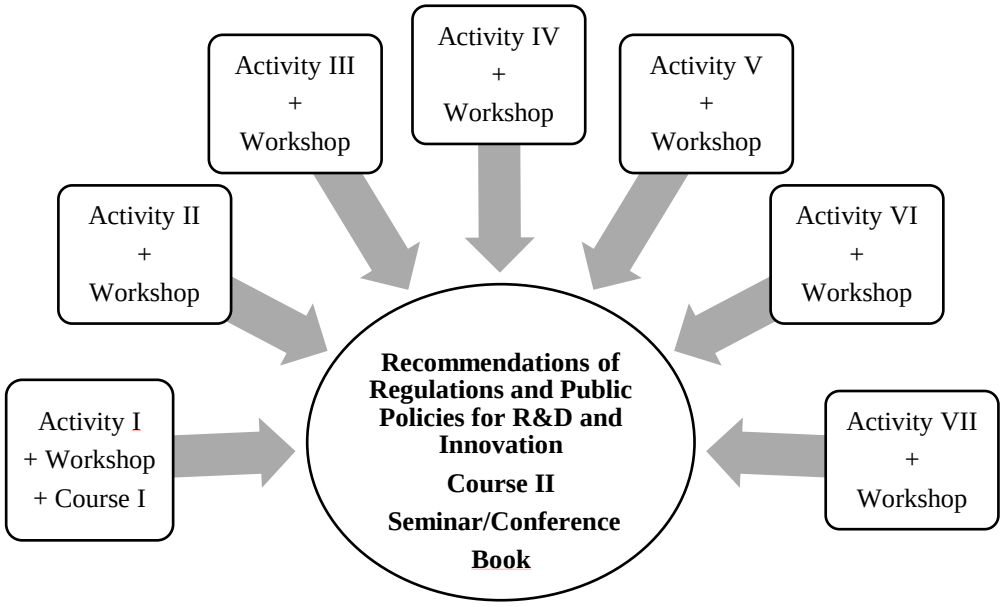
6 - Assessment of international best practices to maximize the value generated by innovation programs: This step includes a selection of successful cases. For those selected cases, it will be developed an extensive bibliographic review and interviews with local specialists in order to provide a detailed assessment of: regulation framework, funding available, electric energy technologies and product promotion using them in its installation, industrial and sectorial policies and government policies to stimulate innovation and the role of startup companies.

7 – Development of public policies and recommendations to stimulate R&D and perceived innovation in the Brazilian electric sector through regulations and laws in order to create a sectorial innovation system.

At the end of each point abovementioned, we will give a workshop to a more specialized target audience, including ANEEL's technical staff. We will also provide seminars to a larger number of stakeholders including public sector institutions such as BNDES (National Development Bank), MIDIC (Ministry of Development, Industry and Foreign Trade), MCT (Ministry of Science and Technology) and provide an international seminar at the final stage of the study. This work will also generate masters and doctoral dissertations, technical and

academic papers. We aim to give courses on the Program to key agents and publish a book on the analysis conducted at the end of the study. Such activities are summarized in figure 2 below:

**Figure 2 – Summary of activities**




## 6. CONCLUSIONS

In this work, we tried to draw some preliminary result on the R&D program conducted by ANEEL and managed by electric energy companies during 2008 and 2014.

The extension of this study must develop a deep analysis in order to propose a new regulatory apparatus designed to promote the innovation dynamics in Brazilian electric sector. Such initiative is very important in face of the perspectives on a new technological paradigm that has been emerging in the electric sector and the particularities of Brazilian Electric Sector.

The proposed study will be coordinated by the Study Group of the Brazilian Electrical Sector (GESEL), sponsored by two large Brazilian energy companies (EDP and ENERGISA), with a strong involvement of several national and international academic centers, suppliers, electric companies, association and government agencies (such as: Mines and Energy, Science and Technology and Industrial Development institutions and organizations).

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