THE BRAZILIAN ENERGY SYSTEMS AND SMART GRIDS – AN ANALYSIS USING THE TECHNOLOGICAL INNOVATION SYSTEMS APPROACH

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ABSTRACT

Although it has one of the largest integrated power generation, transmission and distribution systems in the world, Brazil still faces difficulties in consolidating the various technologies that make up Smart Grids solutions and in executing large projects in the sector, especially in distribution management. Currently, some utilities have pilot projects in operation in a small number of cities, but these projects face several obstacles in the technical, economic, political and legal areas. This study analyses the receptivity to the Smart Grid technologies in the Brazilian electric sector context, by the application of a framework that allows: (i) to identify the obstacles to the implementation of Smart Grid projects and (ii) to propose recommendations for innovation policies. Considering that the Smart Grids solution are composed by a wide gamma of technologies, thus study initially examined the whole smart grid solution, and then focused on an important technology: Advanced Distribution Management Software (ADMS). The chosen framework adopts the Technological Innovation Systems (TIS) concept, that maps the functional pattern of a TIS, allowing the evaluation of its development stage through the identification of the strategic points relevant to its growth. As a final product of the application of the framework, policy recommendations can be proposed to foster the development of research, projects, formation of national companies, implementation and diffusion of knowledge of smart grids technologies in Brazil. Many blocking mechanisms to be faced were identified, such as obsolete regulation contracts; unfavorable tributary environment; bottlenecks in the R&D network formation; high macroeconomic instability in the last years, causing uncertainty and increasing the risk perception; high cost of the smart grids solutions and ADMS, specifically, and lack of good results on smart grid researches. To leverage smart grid projects, the policy recommendations include, among others: specific short-term actions, firstly conferring a new model of regulation of the electric system that allows distributors to make investments. In the medium term, it is necessary to perform a reform of taxes and the way in which services and software licenses are imported. In the long term it is necessary to invest in education and research, stimulating the partnership between agencies, companies, universities, institutes and research centers. The strengthening of this network is fundamental for the development of R&D in Brazil. As a conclusion of this research, it can be said that Brazil has a weak functional pattern combined with specific blocking mechanisms that weaken the Technological System and hamper the development and implementation of Smart Grids technologies.

Keywords: Smart Grid; Electrical Energy; Technological Innovation Systems; Innovation Policies

INTRODUCTION

Brazil is in the tenth position among the countries that have the largest installed capacity for electricity generation and in the eighth position in electricity consumption (EPE, 2013). A large and robust system of generation, transmission and distribution of electric energy provides access to electricity to 99.6% of the population (IBGE, 2013). The Brazilian energy matrix, predominantly hydroelectric (with 65%, complemented by thermoelectric plants with 18%, biomass with 9%, wind with 6%, nuclear with 2% and solar with less than 1%), when in normal operation conditions can produce up to 90% of all the energy needed to supply the cities throughout the 8.5 million km^2 territory (ANEEL, 2016). However, in times of rain scarcity and low plant reservoirs, several gas and coal-fired power plants may go into operation, causing damage to the environment and increasing the price of energy for the consumer.

The Brazilian distribution systems, which operate through concessions to private companies since the privatization programs of the 1990s, face several operational difficulties, such as technical and non-technical losses, high energy prices, size of Brazilian territory, energy thefts, measurement and billing problems, among others. The distribution systems still do not use the latest technologies available in large systems around the world. (Preto, 2012).

Except for pilot projects in operation in a small number of cities, Brazil still does not have large-scale smart grid projects implemented, unlike countries such as the United States, China, Germany, Italy, among others, which are the countries with the largest electricity infrastructure in the ranking. In this context, through the evaluation of the development capacity and adherence of Smart Grid technologies in Brazil, it could be possible to propose the implementation of smart grids as a partial solution to the problems encountered by the distribution concessionaires. This leads to the purpose of this study, which is to analyze the current context of the Brazilian energy sector and its receptivity to Smart Grid technologies, specifically Power Management Software, by applying a framework based on the concept of the Technological Innovation Systems (TIS).

For the development of a complex project in a particular receiver location, such as that involving Smart Grid technologies, there must be a number of factors that support and stimulate it from conception to completion. The application of the framework based on the concept of TIS proposed by Bergek *et al*. (2008) will bring together the main characteristics of the receiver, such as structural components, actors, institutions, research, resources, market, entrepreneurship, incentive/blocking mechanisms, among others, and make possible the identication of obstacles to the implementation of Smart Grid projects and also the proposal of recommendations for innovation policies.

GRID TECHNOLOGIES

Conventional Grid

In the conventional electrical network, the energy flows from the generating units to the final consumer, and there is no exchange of information between him and the generator. Distributors also have no real-time information on equipment installed throughout the distribution network, have low failure recognition, and little maneuverability that guarantees the continuity of the electric power supply in the face of a serious problem, be it load, generation or distribution. It takes a long time for the point of failure to be identified and the problem solved. In addition, energy utilities have very little real-time information on how consumers behave, whether large, medium or small. This lack of iterations hinders the planning and the improvements that periodically need to be made in the electrical networks, besides hampering safety procedures and reliability. Consumers do not receive timely information on consumption and tariffs. In many countries this panorama has changed in recent years with the advent of the smart grids (Islam *et al*., 2014).

Smart Grids

The term "Smart Grid" should be understood more as a concept than a specific technology or equipment. The smart grids consist of a new model of electrical network architecture where there is the application of information technology, through the introduction of meters, communication networks, supervisory and control devices, protection devices and management software, which are interconnected and capable of conferring autonomy and intelligence functions to the electrical network, also allowing manual operation of the system when needed. These technologies, combined, will allow consumers, generation, transmission and distribution companies to have updated real-time data, making the operation more dynamic, efficient and reliable (Amin and Wollenberg, 2005; Park *et al*., 2014; CGEE, 2012).

The vision presented by the International Electrotechnical Commission (2010) covers the concept of Smart Grid as one of the major trends in technology that comprises the processes from the generation of energy to its use by the final consumer. Its complete functionality should encompass all points of the electrical system and be responsible for contributing to its reliable supply. The main purpose of Smart Grid systems is to provide generation, transmission and distribution in a safe and efficient way to consumers.

Furthermore, according to Falcão (2009) and Giordano and Fulli (2012), the introduction of the concept of smart grids will produces a sharp convergence between the infrastructure of generation, transmission and distribution of energy and the infrastructure of digital communications and data processing. In other words, in order to develop smart grid projects, there is a need to integrate technology-related areas with a receptive local technological and production environment. There are significant differences in operation between the conventional power grid and the new smart grids. The benefits of this smart system deployment directly impact social welfare. Giordano and Fulli (2012) also argue that "the digitalization of the electricity grid opens the way to bundle value-added services to the electricity commodity, and possibly shift business value to electricity services in line with the notions of efficiency, conservation and sustainability" and may "contribute to reverse the consumption-driven paradigm of the electricity sector" (p.252).

Advanced Distribution Management Software

Smart grid management software applications are developed based on data processing technology, information technology and electricity concepts with the goal of managing energy processes. Smart Grid systems in general, more specifically distribution network management softwares, are usually deployed and operated by power distributors. These companies, as responsible for the distribution of energy to the end user, have large circuits meshed by cities/regions and, consequently, a varied range of activities needs to be developed so that energy reaches the consumer with quality (Katic, 2013).

Currently, energy companies face several challenges, both in the market and in the technical aspect, such as the growth of regulatory processes, consumer pressures, the need to reduce carbon emissions, the adoption of renewable sources of energy generation and storage, meteorological problems, and network failures. As the price of energy is regulated, the distribution companies seek to reduce their cost of operation to the maximum in order to achieve greater margins, since the tariff adjustment depends on concession contracts with the public regulatory agency (ANEEL) and other aspects. The approval of ANEEL and other institutions such as the CCEE and the Court of Auditors is required.

Power management software, better known as ADMS, is an advanced software application used to improve the operations of distribution networks. ADMS provides tools for dynamic visualization, monitoring and control of the power generation, transmission and distribution network, combined with a large number of analysis, planning and optimization tools, with potential for reducing operating costs, and technical and non-technical losses (Katic *et al*., 2010; Katic, 2013).

The ADMS is an integrated software system for controlling, analyzing and optimizing the operation of the electricity network, meeting the requirements of the distribution utilities, providing: real-time network monitoring and control (SCADA), mathematical network model and power applications (DMS, EMS), incident management in the network (OMS), generation management (MSG) and better use of energy generation sources, efficient fault management and improved network voltage, network analysis (short circuits, protection of relays, losses, reliability, yields, etc.), optimization and reduction of investments in power buildings, automation, etc ., reduction of peak loads in the network and loss of energy, and improvements in energy quality and customer service.

From a sustainable perspective, besides the reduction of losses and optimization of the energy distribution process, another expected benefit of the system implementation is the reduction of greenhouse gases emission. According to Di Lembo *et al*. (2009), it is possible to obtain a reduction of approximately 4% in electric losses. In Brazil, this would make it possible to avoid the start-up of the standby thermoelectric generators. The distribution management software is also capable of helping utilities to manage distributed power systems, such as solar cells and renewable generation.

The ADMS solution is said to be partial since it is not capable of solving all the problems of distribution systems alone. Concomitant to the implementation of smart grids systems, it is necessary to adapt and apply measurement, billing, communication systems, redundancy, and network elements that contribute to the operation.

TECHNOLOGICAL INNOVATION SYSTEMS

This study employs a framework presented by Bergek *et al*. (2008) and based on the concept of Technological Innovation Systems (TIS). The research points out that for the development of a new technology there must be a series of environmental TIS factors that, combined, act in its favour. Hekkert *et al.* (2007) present the concept of innovation as a combination of hardware, software and orgware, where orgware refers to the various components of an innovation system. Therefore, the product of innovation and its incentive/blocking mechanisms are intrinsically related. A complete analysis of innovation in a particular area of knowledge requires that the study extrapolates its technical characteristics and contemplates all factors that may influence its development. This is the central base of the framework by Bergek *et al*. (2008), that presents steps and functions that detail each structural component of the system under study to be applied on Smart Grid technologies in the Brazilian electric sector.

Therefore, Technological Innovation Systems depart from the general definition of systems as a group of components serving a common purpose and establish a methodology for the complete analysis of an area of knowledge, product or technology and its environmental TIS factors. That means that this methodology, presented as a framework, uses a sequence of actions to be developed by researchers and policy-makers in order to identify key issues and to set goals, as shown in Figure 1. In this way, systems can be defined as the set of actors and rules that influence the speed and direction that a technological change advances in a specific technological area (Hekkert *et al*., 2007; Bergek *et al*., 2008; Bergek *et al*., 2015).

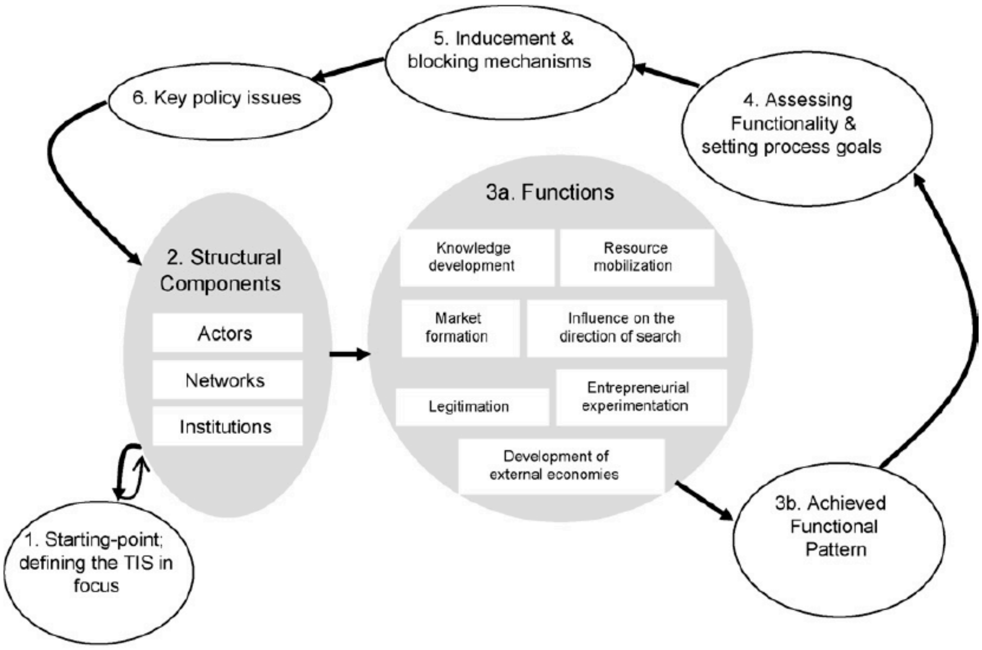

Figure 1: TIS Scheme of Analysis. Source: Bergek et al. (2008).

The success of innovations is largely determined by the way the TIS is built and how it works. The technology or its intrinsic knowledge is hardly incorporated only to the infrastructure of a region. However, each country or region should promote reforms to facilitate the development of a specific technology. In this perspective, the characteristics of the Brazilian electric sector for the receptivity to smart grid technologies will be analysed at every step of the model of analysis proposed by Bergek *et al*. (2008), through a flow chart of research and analysis activities, divided in stages, mainly focusing in the functional analysis, as presented in Table 1.

Table 1: Detailing the Functional Pattern Mapping Process.

Activity	Description
Functional Pattern Mapping	This step aims to determine the extent to which functions are filled in the TIS. Seven functions are listed for the analysis of the functional standard.
Function 1: Knowledge Development and Diffusion	This function captures the breadth and depth of TIS's current knowledge base, how it changes over time, and how it is combined and diffused in the system. It can be expressed in number of publications, product launches, universities and research entities, citations, patents and companies of the branch and the learning curve.
Function 2: Influence in	This function can be measured qualitatively by beliefs in growth

the direction of the research	potential, price incentives, taxes and subsidies, customer articulation, and the extension of regulatory pressures.
Function 3: Entrepreneurial Experimentation	Without vibrant entrepreneurial experimentation, the TIS in question will stagnate. The mapping of this function is done through the number of new operators, including an established diversification index, variety of applications, technology/solution amplitude and the situation of complementary technologies.
Function 4: Market Formation	Generally, the market formation goes through three phases: (1) early stage, where immature markets need to evolve, (2) a bridge market is formed where there is an increase in volume and actors, (3) a successful TIS ends in a mass market, when there is the expansion of technology. The function can be expressed quantitatively (customer numbers, financial and production indices, etc.) and qualitatively (actors' strategy, current position of regulation, etc.).
Function 5: Legitimation	Legitimacy is a matter of social acceptance and compliance with relevant institutions, that is, the new technology and its advocates must be considered appropriate and desirable by relevant actors. The function can be expressed by identifying how legitimacy influences demand, current legislation, the TIS legitimacy and agents that influence legitimacy.
Function 6: Resource Mobilization	The role can be measured in relation to the increasing number of capital towards the TIS, increasing the volume of investments and risk capital, increasing the mobilization of human resources (companies and universities, for example), among others.
Function 7: Development of external economies	This function is not independent, since it depends directly on the other six functions presented, since the generation of externalities will be influenced by the context of performance of each previous function. It can measure qualitatively and quantitatively. For example: the emergence of intermediate and complementary goods, service providers, information flow that help the development of other technology, among others. Therefore, the analysis must be made from the capture of the strength of these functional dynamics through the search for external gains.

The system functions are not independent, but interact and influence each other, further enhancing the dynamism that should be considered in the analysis. For example, *Function 3: Entrepreneurial Experimentation* is intrinsically linked to *Function 4: Market Formation*, since for a strong entrepreneurial movement, there must be favorable conditions and a consolidated market. This combination could boost *Function 6: Resource Mobilization*, since with the growth of entrepreneurial activity, the mobilization of resources will be inherent to the research processes, which require funding and researchers, directly influencing *Function 1: Knowledge Development and Diffusion* and *Function 2: Influence in the direction of the research* (Markard *et al*., 2015).

Therefore, starting from the premise that one function can influence the performance of another, the functional pattern becomes interconnected, characterizing the function system, and creating a virtuous cycle of interactions, as presented by Negro (2007), and shown in Figure 2. A TIS may have a good functional pattern, but if some specific function negatively influences another function in the system, it is possible that this could diminish the positive influence of the latter, and even to compromise the further development of the TIS.

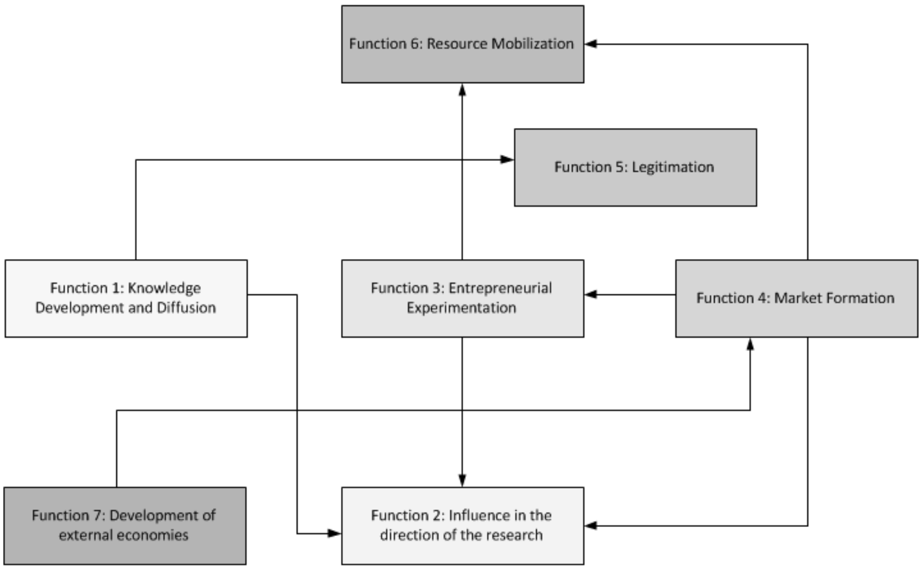

Figure 2: Interaction between system functions, Source: Adapted from Negro (2007).

METHODOLOGY

The methodology consists of the application of the framework of Bergek *et al*. (2008) under the Brazilian context, analyzing the structural components, institutions, actors and networks, laws, norms, standards and rules, taxation, economic model, concession model and operation of the electric system, educational system and developed research, incentive and blocking mechanisms, goals set for the next years, among others. Also, following Negro (2007), a collection of chronological events related to the technology under study was performed. This analysis evaluates the Brazilian context for implementation of smart grid solutions, and ADMS software specifically.

The process of mapping the functions and collecting data will be implemented through a series of activities, with clearly defined objectives, such as research on the academic literature, newspapers, websites, reports, magazines and publications on the subject; data collection and classification; allocation of each event within the structure of the functional pattern; data summary and graphical representation; historical narrative; and results consolidation. For the analysis, according to Negro (2007), it is necessary a separation of the events collected into the categories of the seven functions of the framework of Bergek *et al*. (2008), and also the assignment of a positive or negative signal to each event depending on its relevance to the system. See Table 2.

Table 2: Classification of the measurement scheme of the System Functions.

Function	**Event Categories**	**Sign**
Function 1: Knowledge Development and Diffusion	Conferences, Seminars, Lines of research, development of studies and publications of articles and news.	+1

Function 2: Influence in the direction of the research	Positive Expectations about Technology Establishment of regulations Negative Expectations about Technology Express deficits in regulations	+1 -1
Function 3: Entrepreneurial Experimentation	Initiated / Enlarged Project Interrupted Project	+1 -1
Function 4: Market Formation	Favorable tax conditions or entrepreneurial environment Unfavorable tax or business environment	+1 -1
Function 5: Legitimation	Technology lobbying activities Technology support from government, academia or industry. Lobbying activities against technology Lack of technology support from government, academia or industry.	+1 -1
Function 6: Resource Mobilization	Subsidies or investments Lack of subsidies or investments	+1 -1
Function 7: Development of external economies	Development of positive externalities Development of negative externalities	+1 -1

Then, after the function mapping and assessing process, the blocking and incentive mechanisms are identified. Next, having collected all the information necessary to understand the system, policy recommendations are presented to face the problems identified through the application of the framework. These propositions seek to encourage development through the correction of errors and minimization of the difficulties currently encountered. Success models in other countries were used as a suggestion for specific reforms of Brazilian innovation policy items. Figure 3 summarizes the methodology used in the study.

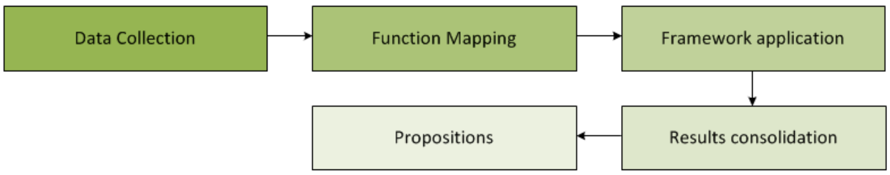

Figure 3: Study methodology.

ANALYSIS, RESULTS AND DISCUSSION

In this section are presented the analyses related to each stage of the Technological Innovation Systems framework. From the point of view of a systemic model, the Brazilian technological innovation process has several characteristics that hinder both the research process and the diffusion of new technologies. Understanding that adjustments made in specific points of the system can positively alter and enhance the results, the factors that contribute negatively or positively to the development of the TIS, and the propositions to solve such questions, will be examined.

Steps 1 and 2: Starting Point and Structural Components

The construction of the functional pattern of the system is the most demanding stage of this work, since it requires a comprehensive search for events, selection, arrangement of empirical data into categories and functions, plotting of the graphics and development of the sequential narrative. However, the framework is not limited to the study of functions, but on the contrary, functions are part of the framework proposed by Bergek *et al*. (2008) and, therefore, each stage of analysis will be presented in a specific item. Only at the end of the complete analysis process will the actual representation of the TIS be obtained, which will combine results from the study of functions, the evaluation and establishment of process goals, the identification of blocking and incentive mechanisms and the development of policy recommendations. Table 3 shows a summary of the first steps of the framework.

Table 3: Summary of the framework execution first part.

Nº	Step	Description
1	Starting Point: Definition of the TIS in focus	Smart Grids in Brazil / ADMS Systems
2	Identification of Structural Components	Actors: Regulatory bodies and entities, producing smart grid technology companies, customers, educational institutions, research institutes, development institutions, government, competitors, suppliers and investors.

In innovation networks, even if unconsciously, innovation activities are coordinated and the result of such coordination is the development of innovative products and services. Brazil has some difficulty in building networks and still relies excessively on government actions to develop large projects. This dependence, together with the lack of resources from of the public sector to support large projects, means that there is a bottleneck in the networks formed. In countries with large State participation, such as Brazil, there is a need for government actions in the areas of regulation, financing, infrastructure, education and the patent system. Presently, the country lacks an effective government commitment to improvements in these areas, and stronger support to the formation of new networks. An institutional model of networks and connections among actors is shown in Figure 4.

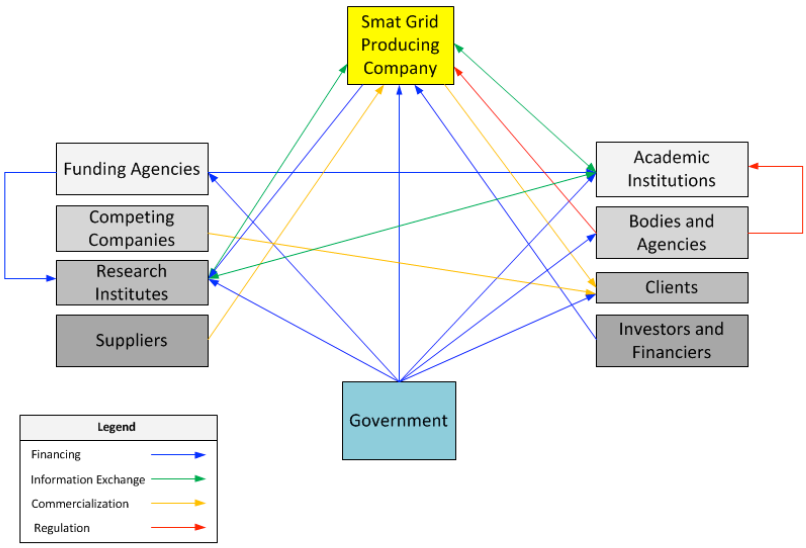

Figure 4: Network of the Smart Grid Innovation System in Brazil

Step 3: Mapping the Functional Pattern

Through a more detailed and chronological analysis of the functions it is possible to identify the differences between the functional patterns of the Smart Grid TIS as a whole and the management software TIS, specifically, as well as their levels of development. Following the methodology proposed by Negro (2007), graphs were plotted containing the compilation of data categorized into functions and gathered by year. See Figure 5. The events regarding smart grid systems presented in each graph were collected from 2008 to 2016. Next, the classification referred to in Table 3 and the contextualization of the sequence of events with the evolution of TIS were made.

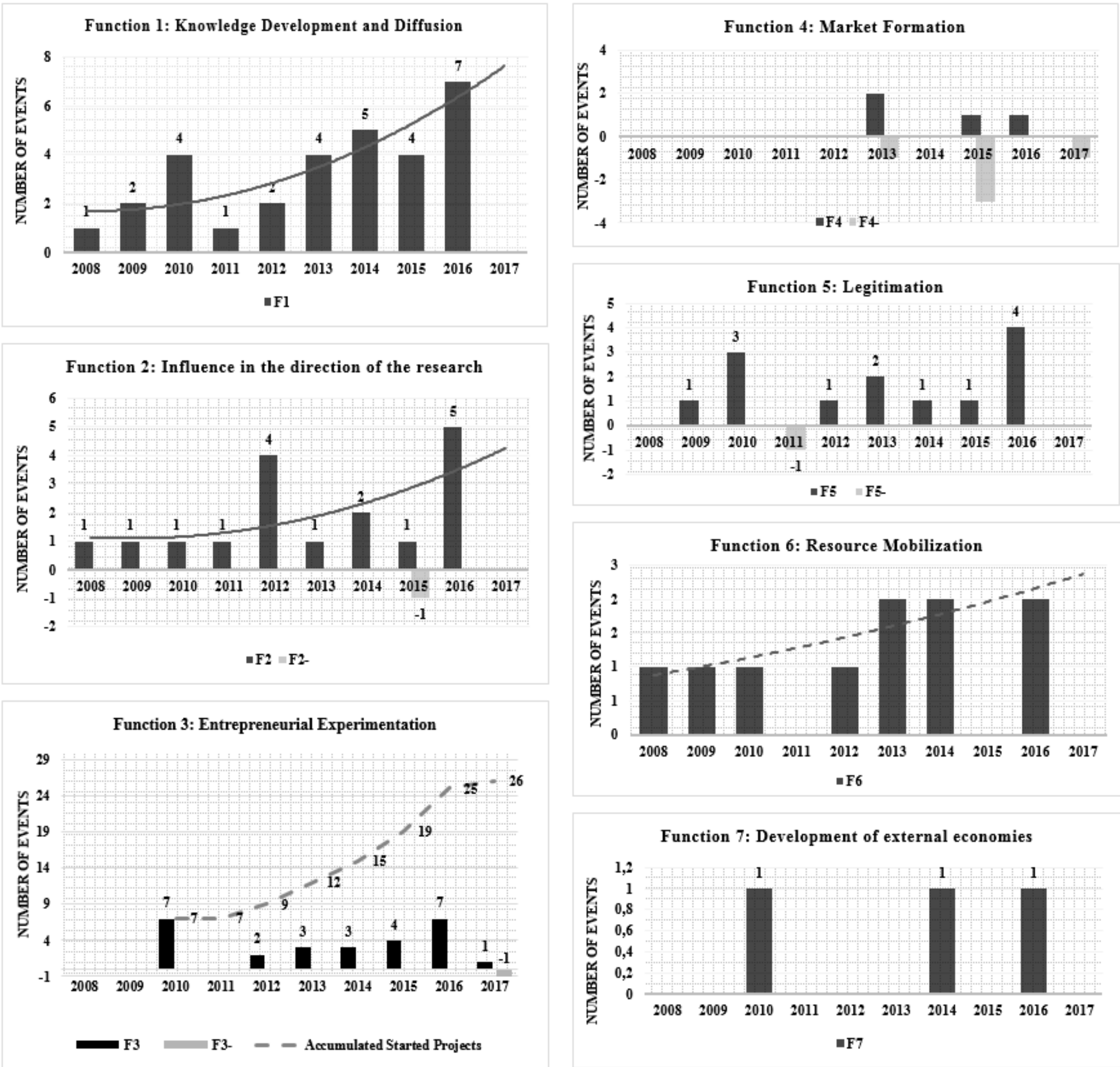

Figure 5: Consolidation of mapped and classified events

Table 4 summarizes the results obtained during the analysis of the functional mapping of the system.

Table 4: Summary of the Functional Pattern Analysis Results.

Nº	Step	Description
3	Functional Pattern Mapping	To verify to what extent the functions are currently consolidated in the TIS, that is, to analyze how the system behaves in terms of a functional standard that is a set of key processes. This functional pattern manifests itself in terms of seven functions considered into the framework.
3.1	Function 1: Knowledge Development and Diffusion	Large number of publications, holding of various forums and seminars, a significant number of researches being carried out in the area. Knowledge in a good diffusion stage.
3.2	Function 2: Influence in the direction of the research	Positive expectations about technology, expressed lack of regulatory. Increasing research funding.
3.3	Function 3: Entrepreneurial Experimentation	Several projects started. Several companies in the segment.
3.4	Function 4: Market Formation	Favorable tax conditions for some components of the solution. Unfavorable entrepreneurial environment. Implementation of several pilot projects.
3.5	Function 5: Legitimation	Technology support from government, academia and industry. Legitimacy developed.
3.6	Function 6: Resource Mobilization	Large number of companies developing solutions and funding research.
3.7	Function 7: Development of external economies	Several markets are organizing to supply the demand and enjoy the benefits of smart grids.
4	Assessing Functionality and setting process goals	The Smart Grid TIS, in fact, is growing in Brazil. However, some factors limit this growth and create obstacles to the development of technology in the country, making the volume of negotiations and economic activities only a fraction of the estimated potential.

Figure 6 represents the consolidation of the functions in a radar chart. It is possible to verify the large incidence of events allocated in functions F1, F2 and F3. This configuration helps to identify that the TIS is in its initial stage and also the level of each function. Not so often as the functions mentioned above, but with a certain incidence of events, Function 5 - Legitimation demonstrates that solutions are recognized in the market between potential consumers and entities.

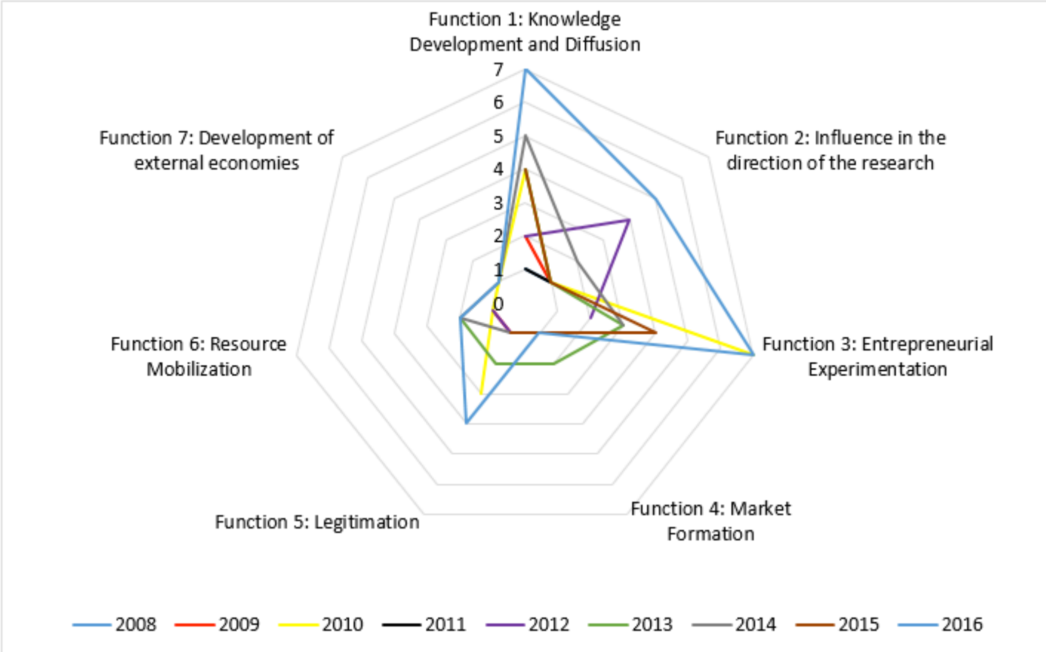

Figure 6: System Function Dynamics.

A TIS is completely influenced by the environment in which it is inserted. Thus, when performing an analysis of the functional pattern, the characteristics of this environment are manifested in the form of mechanisms. These mechanisms may have a positive or negative influence on the TIS. Mechanisms that exert a positive influence can be called incentive mechanisms, whereas mechanisms that exert negative influence can be called blocking mechanisms.

This stage of the framework is concerned with identifying mechanisms that induce the TIS, as presented in Table 5. From a policy formulation perspective, it is important to know the mechanisms that contribute to shaping the dynamic nature of a system. There may be different factors that block the development of functions, and to achieve a higher functionality, it is necessary to know these factors and to take actions in the sense of mitigating the blocking mechanisms and intensify the incentive mechanisms. Therefore, it is quite possible to establish a relation between the mechanisms and functions presented. Since the functions have already been identified and analyzed in the previous items, it remains to list the blocking and incentive mechanisms.

Table 5: Framework Final Steps

Nº	Step	Description
5	Incentive and Blocking Mechanisms identification	*Incentive mechanisms*: (1) belief in the growth potential and legitimacy of technology; (2) R&D financing by ANEEL, private companies and research institutes, and (3) articulation of well-defined demand. *Blocking mechanisms*: (1) unfavorable tax environment; (2) unfavorable regulatory environment; (3) lack of knowledge of the solution and fit into the clients' needs; (4) low result from research and (5) few university programs.
6	Key policy issues	(1) promote tax reform or changes in TIS specific legislation; (2) capacitate local labor; (3) lobby (F5) to be done in the agencies to update the governing energy concessions rules; (4) creation of university programs, conduction of research and training of end users (clients); (5) improvement of institutional networks.

Figure 7 shows the interrelationship among the functions, the incentive mechanisms, the blocking mechanisms and the key policies recommendation. In order to face the unfavorable tax environment, that leads to high price of smart grid solutions in general and more specifically of management software, there are two solutions: (1) to promote a tax reform or changes in the specific legislation for the TIS, like harder regulation on the level of losses, tariffs readjustment, dynamic price by demand and consumption; and (2) training local manpower. The first solution is to reduce the tax rates on imported products, software licenses and services. The second solution aims to empower the local labor force to avoid such taxes. These actions depend directly on the entrepreneurial experience, the formation of the market, the expectations about the solution and the mobilization of resources, these functions being the focus of the actions.

The unfavorable regulatory environment must be tackled through lobbying (F5) to be done in the agencies, to update the rules governing energy concessions. This modernization would bring lower costs to the concessionaires and, consequently, to the final consumer, who would have access to a more reliable energy. This is because smart grid technologies reduce losses from technical processes and theft of energy. This reduction of losses would contribute to lower the implementation costs on the tariff readjustments.

Lack of knowledge about the smart grid solution may be one of the causes of poor research results, and both may be a consequence of having few university programs with specific training in smart grids. This is a typical example of how interdependencies between mechanisms can generate chained negative impacts. Establishing a national research and knowledge program in smart grids is one of the actions that would mitigate the negative impact of these mechanisms. This program would cover university programs, research, and the training of end users (clients). The latter also aims to mitigate the possible lack of legitimacy (Function 5) among some clients.

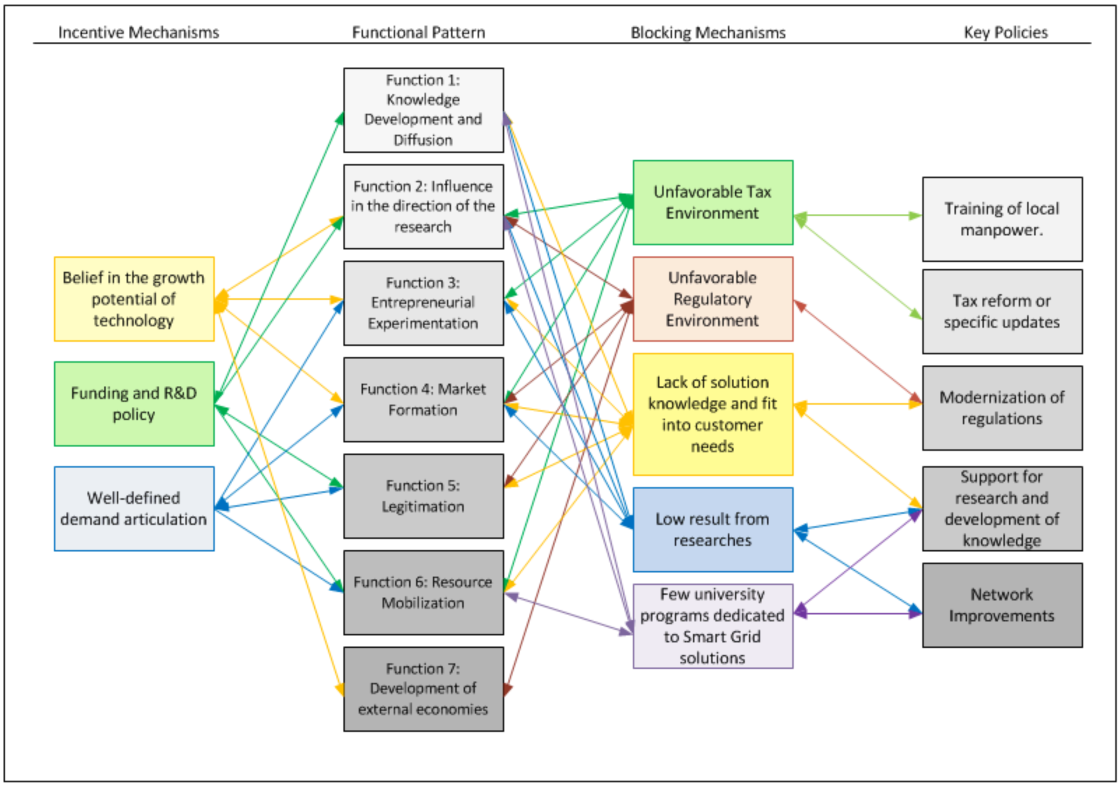

Figure 7: Relations between Mechanisms, Functions and Recommendations for Innovation Policies

About Legitimation, it is important that consumers are engaged in developing smart grid technologies. In a scenario where consumers demand distributed generation resources, remote control over electronic equipment, real-time information, among others, utilities will need to adapt to this new level of electricity supply. From this perspective, it is possible to strengthen the system through the legitimacy of smart grid solutions in society. The policy-maker can use this systemic feature to strengthen the functional pattern of the system (Randelli and Rocchi, 2017).

Four important implications can be identified for policy makers to leverage TIS development: (i) the existence of an ambitious and stable long-term policy strategy; (ii) the existence of demand incentives through tariff policies (feed-in tariffs); (iii) a credible political commitment to technology, of great importance for an emerging TIS; and (iv) flexible adjustments of the elements of the policy mix, which seems vital to sustain development continuity of the TIS (Reichardt et al., 2015). Figure 8 presents a more detailed plan of actions on key policies and the implications that should be taken into account.

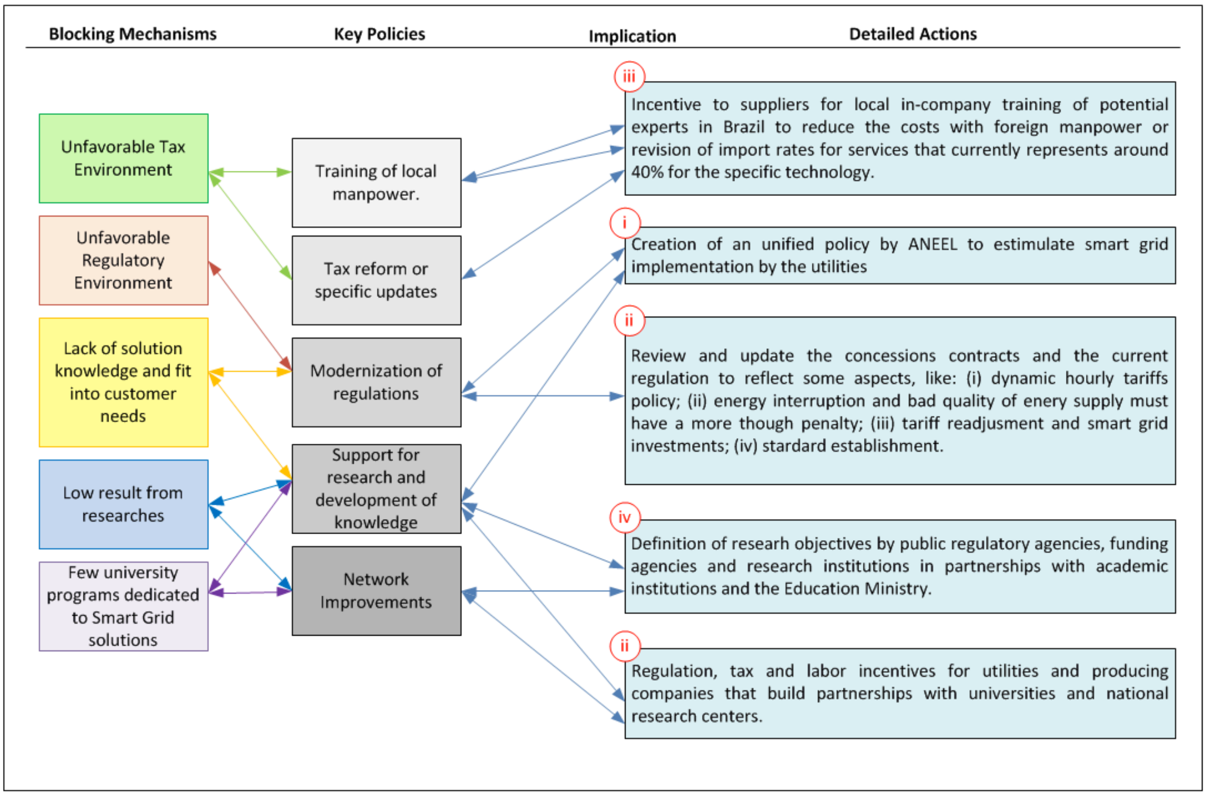

Figure 8: Blocking Mechanisms, Key Policies and detailed actions.

Distribution Management Systems Specific Study

Heretofore, this study presented its development on smart grid technologies (as a whole) and their deployment characteristics in Brazil. As noted earlier, smart grids are a composite of several technologies and, consequently, there are many innovation systems. When dealing with smart grid, this study could focus only on applying the framework of Bergek *et al*. (2008), complemented by a methodology recommended by Negro (2007), and present the results. To analyze more specifically the technologies that compose smart grid solutions there are two options: (1) to elaborate a complete study encompassing several smart grid technologies or (2) choose a specific technology and study it. The first option would require a large amount of time for its development, resulting in a larger work than the one proposed for the research. So, the second option was chosen, focusing on Distribution management software technology for a more specific analysis. During the study for the technologies of smart grids as a whole, the ADMS TIS events were also captured, and the framework for the ADMS was executed, since they are included in the Smart Grid TIS.

Table 6 consolidates the results of the two innovation systems framework considered, presenting a parallel between them in terms of the functional pattern, and relating the functional pattern of the ADMS TIS and the practical local characteristics of the system. The distribution management software TIS in Brazil is in a Formative phase, that is, it is still in the initial phase of system development. There is little dispersed knowledge in the society about the solution (-F1); few companies consider that the system is essential for their daily operation (-F5); there are very few suppliers for this solution (-F3); the tax conditions and the environment for entrepreneurs are also not favorable (-F4); there are few resources mobilized for this specific issue (F6); and the persistent regulatory deficit, as in the Smart Grid TIS, reduces the benefits after the implementation of this type of system (-F2).

Table 6: Functional Pattern Consolidation Comparison and ADMS practical characteristics

Function	**Smart Grid TIS Framework Outputs**	**ADMS TIS Framework Outputs**	**ADMS Specific Events Analysis**
Function 1: Knowledge Development and Diffusion	Large number of publications, holding of various forums and seminars, a good number of researches being carried out in the area. Knowledge in a good diffusion stage.	Little number of publications, little exposure in forums and seminars, scarce number of researches being conducted in the area. Knowledge at a low diffusion stage.	Low level of local knowledge for research development and even for system deployment generate cost increase.
Function 2: Influence in the direction of the research	Positive expectations about technology, expressed regulatory deficits. Research funding.	Positive expectations about technology, expressed regulatory deficits. Research funding.	High level of interest rate discourages research funding.
Function 3: Entrepreneurial Experimentation	Several projects started. Several companies in the segment.	No complete project started. Few companies in the segment. Only a national company.	High project cost makes project execution impossible. The high technology and consequent high cost of importing services and licenses discourages the entry or development of companies in the segment.

Function 4: Market Formation	Favorable tax conditions for some components of the solution. Unfavorable entrepreneurial environment. Implementation of several pilot projects.	Unfavorable tax and business environment conditions.	High incidence of taxes on services and licenses. High interest rate that discourages investments.
Function 5: Legitimation	Technology support from government, academia and industry. Legitimacy developed.	Technology support from government, academia and industry. Legitimacy in good state of development.	N/A
Function 6: Resource Mobilization	Large number of companies developing solutions and funding research.	Scarce number of companies developing solutions and funding research.	High labor cost and little local resource for research.
Function 7: Development of external economies	Several markets are organizing to supply the demand and enjoy the benefits of smart grids.	Few markets involved in solutions.	N/A

As presented above, the systems are in different stages. While the Smart Grid TIS is in the expansion phase, the ADMS TIS is in its formative phase. Because it is a system internal to the Smart Grid TIS, the ADMS TIS receives influences from the same factors that influence Smart Grid TIS. For the Smart Grid TIS, the obstacles are manifested as technical difficulties and lack of knowledge about the solution, high implementation cost and long return on investment. The ADMS TIS has the same bottlenecks. Price is the main reason that discourages utilities from executing this type of project. As shown in Figure 9, the large amount of software licenses and foreign professionals brought to the country results in high implementation costs, rendering projects nonviable. This increase in prices is due in large part to the high tax burden and to the need to contract foreign exchange hedge to mitigate possible exchange rate variations. Therefore, the lack of a legitimate national solution pushes up prices.

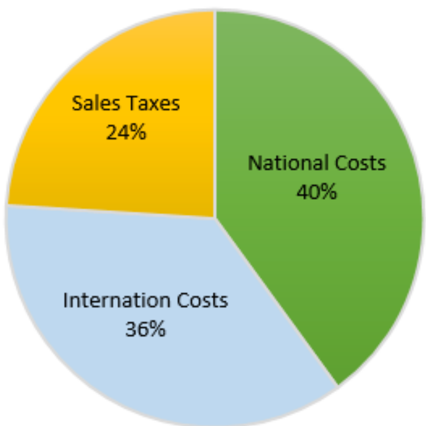

Figure 9: Detailed composition of the project costs.

FINAL REMARKS

The objective of the analysis in this work was to sketch and organize the way in which the evaluation of technological innovation systems should be done. After the execution of the framework, the entire TIS extract was obtained. The scheme was divided into six carefully executed steps, with demanding data search and organization of the information collected. The main advantage of using this scheme is that the study focuses on what is within the reach of the system or technology, not general and structural attitudes, as it analyzes system failures (in terms of the functional standard or key processes) and not market and/or structural failures.

Thus, by analyzing the weaknesses of the TIS functional pattern, identifying the blocking and incentive mechanisms, and making the formulation or propositions of policies to be developed, the end of the analysis process is reached. The main application of this scheme is to identify system failures in a functional pattern, their relationship to the mechanisms, and to provide a device where policy-makers can query the results. The analysis of a TIS can also be performed via benchmarking, that is, a comparison with other TIS that can bring benefits and anticipate results. The comparison between TIS is also an arduous task and serves as a suggestion for future work.

As for the results, it was expected that the TIS of smart grids was in its growth phase, while the TIS of management software was in its formative phase. Brazil has problems to develop research in several areas, and this is a structural problem that is often external to the innovation system. The system needs to be built and acquired in a format that will overcome these difficulties.

The propositions made must be applied urgently, since, as mentioned in several articles, countries around the world already develop large-scale smart grid technologies, while Brazil lags behind. The study shows the specific points that should be prioritized and which actions (public or private policies) should be developed.

At the end of the implementation of the framework, suggestions for actions for innovation policies were proposed. These recommended policies need to be discussed among regulatory institutions, manufacturing companies, universities, research institutes and utilities. Brazil needs to build an official network among these agents. Several countries are effective in building and strenghtening these networks.

In practice, it is also necessary to have a research incubation program between companies and universities. The cheaper labor of early-career professionals from educational institutions can reduce the cost of research and engages the researcher in the field from the very beginning of his academic development. Many universities lack the structure and expertise to conduct advanced research, which would be achieved by this partnership.

The study in this paper presents the Brazilian case and has a wide perspective of analysis. Further studies could choose one of the smart grid technologies, like meters, telecommunication systems, distributed resources, etc., or apply the framework in another country. Different countries have different incentive and blocking mechanisms, and the analyses could generate benchmark studies. It would be also interesting to see studies that use a numerical approach and compare them to the theoretical recommendations.

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