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Innovation in the Brazilian Electricity Sector: current scenarios and trends

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Abstract— *There are three main trends in the electricity sector in upcoming years: digitalization, decentralization and decarbonization, changes that are an opportunity for utilities to become more profitable through innovation development. In this scenario, the establishment of cooperation networks between large companies of the electricity sector and start-ups may be a solution to foster innovation, and the purpose of this article is to analyse whether this solution may also be suitable for the Brazilian context. In order to discuss and characterize the innovation process in the Brazilian electricity sector companies, a review of the service innovation literature and regarding the role ofstart-ups to innovation generation in the electricity sector was carried out. Furthermore, data from the latest edition of the Brazilian National Technological Innovation Survey (PINTEC) was selected in order to analyse the main characteristics of innovation in the Brazilian Electricity Sector. The results from this article confirms findings from specialized literature that states that service companies have a larger outward degree of innovation development in comparison to inward innovation, which, in turn, confirms the importance of network relationships for companies to gain access to a broad and versatile set of resources for innovation.*

Keywords— ***electricity sector; large companies; innovation; start-ups; Brazil.***

I. INTRODUCTION

The service sector can be defined as the set of economic activities that produce time, place, form, and psychological benefits. Thus, the sector involves very distinctive activities, such as personal services, technological services, corporate services, non-profit services, and services for distributing goods and information. Services are different from products, because services are intangible and subject to regulation and production and consumption of services are normally simultaneous (Miles and Metcalfe, 1997; Kon, 2004).

During a long period, the studies of service activities played a secondary role in company performance analyses. As demonstrated by Kon (2004), even traditional entities that classify economic activities, such as the United Nations (UN) and the United States Census Bureau, have differences regarding service sector classification, due to the nature of related activities.

The economic performance analysis in developed and developing countries show a growing importance of the service sector from the end of 20th century, both referring to job generation and added value generation (Calabria et al, 2013; Kubota et al, 2010; OECD, 2005; Burdon *et al.*, 2015). Calabria et al (2013) show evidence of the growing importance of the service sector at the macroeconomic level and its role in the microeconomic dynamics, as recent transformations in industrial structures address to a product/service integration(Howells, 2000). In this sense, Gallouj and Djellal (2010) created a new classification of service activities and discussed the importance of such

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activities for corporate innovation and performance. Calabria et al (2013) claim that a scientific field of study regarding the service sector was created in the 2000s, with contributions to different areas, such as service innovation, management, engineering, design, and marketing. The contributions to the field suggest that value creation in the service sector is done with customers (Chen et al, 2014; Van Riel et al, 2013; Gustafsson et al, 2012; De Vries, 2006). In this context, innovation activity assumes an increasing collaborative nature (Rusanenet al, 2014).

These discussions are important to analyse the strategies of the electricity sector distribution companies (DISCOs), which involve a natural monopoly activity in a regulated public services environment. There are three main trends in the electricity sector in the world in upcoming years: (i) digitalization: new downstream will provide new services and transform the energy supply approach to a service-based model; (ii) decentralization: expansion of renewable energies with intelligent network management and peer-to-peer markets in which consumers are at the centre of the process; (iii) decarbonization: the generation of electricity will continue to be transferred in a constant and continuous form to a more sustainable mix, due to the Paris Agreement (Eurelectric, 2016; Honebeinet al, 2012; Livieratos & Lepeniotis, 2017). Besides that, the diffusion of Distributed Generation (DG) and some recent regulatory and technological changes are introducing a new scenario for market diversification. The fact that consumers may now produce their own energy, becoming producers/consumers or prosumers, sets new challenges for the DISCOs, which may lose part of their income due to customers energy generation, reinforcing the importance of promoting innovations.

The changes that the electricity sector is going through are an opportunity for utilities in the electricity sector to become more profitable, because the development of new forms of innovation allows the appropriation of gains from the operation, and companies want to have a more relevant role for society(Wood, 2016; Butler, 1981; Johnson & Bate, 2003).More innovation development has been repeatedly identified as a common denominator of successful enterprises (Piperopoulos & Scase, 2009; Vaccaro et al, 2010; Borjesson & Lofsten, 2012) In this sense, the establishment of cooperation networks between large companies of the Brazilian electricity sector and start-ups may be a solution to foster innovation. The companies in the electricity sector may also set partnerships with technological parks, incubators, and accelerators, as well as organise competitions and awards for innovative start-ups.

The article analyses innovation characteristics of Brazilian electricity sector companies based on the concept of service innovation and data from results of official statistics. For this purpose, a review of the service innovation literature was carried out to serve as a basis for the study of innovation in the Brazilian electricity sector. In addition, contributions regarding the role ofstart-ups to innovation generation in the electricity sector were presented, with an emphasis on the different ways in which start-up scan contribute to R&D strategies in companies in this sector. Finally, data from the latest edition of the Brazilian National Technological Innovation Survey (PINTEC) were selected in order to analyse the main characteristics of innovation in the Brazilian sector.

The article is divided into five sections in addition to this introduction. The second section briefly exposes the recent results of studies on service innovation and shows how service innovations are related to organisational innovations. The third section presents the role start-ups may play in developing innovations in the service sector and analyses the possible implications of the focus on service innovation for corporate strategies in the electricity sector. The fourth section details the methodology used in the article. The fifth section discusses in detail the main innovation characteristics of the Brazilian electricity sector. The article ends with a conclusion that condenses the main discussion points of this analysis.

II. SERVICE INNOVATION PROCESS

According to OECD (2005), innovation is a continuous process that companies constantly use to enforce changes in products and processes and to search for new knowledge. Innovation can be classified in four types: (i) the implementation of a novel or significantly improved product (good or service); (ii) a new process; (iii) a new marketing method; or(iv) a new organisational method in business practice, organisation of workplace, or external relations (Schumpeter, 1942). The goal is to achieve an increase in productivity and/or commercial performance, materialised in different adaptations related to company demand, such as improvement in the product quality, new positioning, or entrance in new markets, or associated with corporate production capacity.

The innovation process is an idiosyncratic process where firms individually intend to answer to the particularities of their markets or to transform markets from the organisational learning they have accumulated: greater capacities will result in more possibilities to capture opportunities (RICYT, 2001). In order to explain the set of learning efforts that enable different capabilities, Lall

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(1992) and Bell and Pavitt (1993) created a classification of different types of corporate technological learning considering differences on investment mobilization, production, and relationships between firms and the economy.

Most innovation activities in developing countries are related to organisational streamline and modification or improvement of existing technologies(RICYT, 2001). In thiscontext, innovations will tend to be less developed in internal R&D departments within companies and more likely to be acquired form other companies or institutions. Therefore, it is necessary to pay attention to the company's external relations and to the conditions where such relations are built on. Thus, company-specific aspectssuch as lack of specialised, trained personnel or cost of factors, as well as external economic aspects such as raised costs and deficiencies in demand of different sectors, legal factors such as tax regulations or rules will become barriers for innovation (Rajapathirana; Hui, 2018). Barriers may also be established by factors that compose the innovation scenario, such as macroeconomic uncertainty, deficiencies in logistic infrastructure, institutional fragility, lack of social awareness on innovation, and corporate nature of risk aversion, among others(RICYT, 2001). These aspects explain the importance of several instruments of public policies for business and training support (Mazzucato, 2015; Chaminade and Edquist, 2010).

The organisational change is an extremely significant aspect in the innovation process, because it impacts the company's performance and its absorption capacity. Knowledge plays a core role in increasing productivity and economic growth, not only in technology-intensive industrial sectors, but also in traditional manufacturing and in different activities across the service sector(Gallouj et al, 2015; Mina et al, 2014; Hu et al, 2009; Dogdson & Hinze, 2000).

There is an increasing focus on studies and publications on innovation in the service sector (Dotzel, Shankar & Berry, 2013; Ordanini & Parasuraman, 2010; Carlborg, Kindström & Kowalkowski, 2014;Toivonen& Tuominen, 2009).According to Witell et al (2016), specialized literature defines service innovation through an assimilation (Ko& Lu, 2010; Pearson, 1997), demarcation (Hertog et al, 2011; Agarwal & Selen, 2009) or synthesis perspective (Gallouj & Weinstein, 1997; Sundbo, 1997; Drejer, 2004). The demarcation approach defines service innovation as a new or considerably changed service in the company or the introduction of a new or completely changed innovation process for the company(Hertog et al, 2011), which is a good approach to explain innovation in a specific sector, (Witell et al, 2016) such as the electricity sector.

In the service sector, innovation activities tend to be organised less formally and have a more incremental, continuous and less technological nature (Chae, 2012; OECD, 2005). In other words, service innovation activities tend to be more based on exploitation, when companies innovate based on its own resources, than on exploration, when companies search for new resources to innovate.T hese activities may include significant improvements referring to how they are provided, the addition of new functions or features to existing services or the introduction of services. Nonetheless, there is a greater convergence in the *modus operandi* of industry and services, with the interchange of competition, technological, and organisational standards between both these segments: industrial activities are becoming more dependent on intangible inputs, while some service segments are depending more on investments in physical resources such as logistics, transportation, and telecommunications networks (Howells, 2000). These factsmay eventually complicate the identification of service innovations in terms of isolated events.

To define service innovation it is alsoworthwhile to stress the analysis of such activity. A pioneering effort in such direction was made by Soete and Miozzo (1989), who adapted the taxonomy proposed by Pavitt (1984) to industrial companies in order to characterize different innovation possibilities in the service sector. According tothese authors, the companies in the service sector can be classified as follows: science-based services and specialised suppliers; production- and scale-intensive services; network services; and supplier-dominated services. Science-based services and specialised suppliers include knowledge-intensive business services (KIBS); their dynamics have attracted a lot of attention from researchers due to their important role in organisational innovation (Miles, 2003). Examples of these services include computer science, Research and Development (R&D), as well as jurisdictional consultancy services. Financial services are examples of production- and scale-intensive services, because they need provision of several back-office tasks. Network services depend on physical networks to be provided, such as telecommunications and transportation services. Finally, in supplier-dominated services innovations are derived from equipment innovations. Examples of supplier-dominated services include health and personal services, for instance catering, beauty services and retail sales. Metcalfe and Miles (1997) observed that utility services, such as the provision of water, gas, electricity, may be characterised as network

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services, even if this classification is not usual among studies in the sector.

The subsequent studies on service innovation took several directions. Some studies adapted the concepts developed for the industrial sector to the service sector (Barras, 1986;Utterback&Abernathy,1975); others were based on empirical approaches, using available statistics; while other studies emphasised the role of the user-producer interaction underlying the service innovation in order to discuss the traditional innovation division in product and process innovation(Gallouj & Savona, 2010). According to Gallouj and Savona (2010), there are still several doubts to be answered by studies on service innovation due to the wide range of activities in the sector and the specificities of their production. These authors suggest that the role of consumers in the innovation process needs to be better analysed, as empirical studies are still focused on trying to explain the role of service activities in productivity. Also, there are research areas that need to be explored, such as utility services, environmental services, and social services. The dominance of studies on KIBS in the literature of service innovation leads us to pose the following question: which capabilities are needed for innovation in other service types?

Hidalgo and D'Alvano (2013) demonstrate that many service companies have a larger outward degree of innovation development than their inward degree of innovation development, reinforcing the fact that innovation processes in this sector possess greater emphasis on consumers and suppliers than in other segments. In addition, the authors demonstrate that service firms engage in a general cooperation mode, rather than an organizational cooperation mode, considering suppliers, consumers, universities and R&D centers in their innovation processes, without having a preference for any specific type of innovation.

Rusanen et al (2014) also claim that service firms use network relationships to gain access to a broad and versatile set of resources for innovation, such as know-how, contacts, information, learning environments, financing, software, and reputation. The authors point out that firms seek access to strategic resources for service innovation in a wide variety of actors, such as consumers, suppliers, social contacts, consultants and universities, which reinforces the importance of networks in which firms are embedded. The study also points out that most of the key relationships to access resources that are important for innovation are informal, such as social contacts, arm's-length relationships, close exchange relationships, and development relationships.In this sense, start-ups have a key role in fostering scalable and repeatable innovation (Blank, 2010). As defined by Blank (2010), start-ups are companies created by a group of people searching for a repeatable and scalable business model working under extreme uncertain conditions. And they are also recent, dynamic, lean and rapidly scalable companies that can develop innovations for consolidated sectors due to their organizational characteristics, in addition to developing new business models and processes (Ghezzi, 2017; Mian et al, 2016; Bandeira et al, 2016; Baek & Neymotin, 2016; Anthony, 2012).

Authors that study entrepreneurship consider the creation of new firms is a significant mechanism for conceiving and diffusing innovations (Acset al, 2006; Baraldi et al, 2018; Ciabuschi et al, 2012). Based on this assumption, empiric studies in different countries have been trying to identify the determinants for the creation ofstart-ups. These studies show that the regional concentration of highly qualified human resources is a determining factor of start-up creation (Fritsch & Falck, 2002; Ikeuchi & Okamuro, 2010). Nevertheless, not all start-ups survive with competition. Therefore, the availability of qualified human resources and a favourable environment to the creation of new firms are necessary conditions, but not sufficient, to creating innovative start-ups in the service sector.

To sum up, one of the results of innovation is organizational learning and the improvement of the firm´s capabilities related to organizational learning enables firms to take more advantage of market opportunities. The review of the literature on service innovation presented in this section suggests that electricity companies may be characterized as network companies and as such are strongly dependent of external innovation provided by suppliers, consumers and other member of their network. In this sense, start-ups may play a key role in a company's networks to foster innovation in the electricity sector. We will address this issue in the next section.

III. THE ROLE OF START-UPS IN THE DEVELOPMENT OF SERVICE INNOVATIONS

The companies in the electricity sector may be considered as network companies, because they organise themselves in a physical distribution network that ensures the provision of utilities. Therefore, the R&D strategy in electricity sector companies should focus not only in the development of internal learning, but also in the establishment of cooperation networks, as service innovation depends on interactions with users and suppliers, as previously discussed. Furthermore, empirical studies on spatial concentrations of innovative activities

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show that the electricity sector develops technology based on cooperation networks (Corsatea & Jayet, 2014). Utility companies usually outsource research activities, enabling other producers of technologies to develop new solutions for electricity from alternative sources due to the ongoing energy transition.

In 2015, DISCOs invested approximately R$ 12.3 billion on the purchase of new equipments, on personnel training, on awareness campaigns, on network expansion, consumer attendance, and actions against thefts and frauds (ABRADEE, 2016). Therefore, companies are performing great efforts to improve their capabilities to foster their competitiveness. The strategies of companies in the electricity sector can be based on three aspects: innovation, diversification of activities or internationalization (Whittington, 1993; Dojic, 2017).Ratinen and Lund (2014) report that the basic characteristics of an innovation-based strategy are directly related to the creation of new business opportunities, such as start-up support programs.

That is because as shown by Criscuolo et al (2012) the service sector start-ups are more likely to develop product innovations and register higher innovation returns than established firms. For scale-intensive services, the size of the companies in the sector leads them to outsourcing especially in activities that demand higher agility in developing innovations. For example, companies in the financial sector may recur to cooperation with start-ups to develop new services such as applications for customer interaction. Companies in the supplier-dominated services segment may benefit from cooperation with start-ups, since they can act as providers of new solutions to offer better services. For example, the lodging and catering sector has been strongly impacted by the diffusion of applications provided by start-ups that facilitate price comparisons and enable reserves. Smaller-sized establishments in this sector often need to introduce organisational innovations to adjust themselves to demands created by such applications. Network service companies, such as companies in the electricity sector, may recur to start-ups to develop specific technological solutions for certain regions or to introduce differentiated services in their set of services for consumers.

In this context, in Europe, in order to maintain their leading position, large companies in the electricity sector are developing Corporate Venture Capital (CVC) programs to foster start-ups. These programs integrate a set of initiatives that may constitute a broader Open Innovation approach. In general, CVC-led investments focus on the development of networks and new technologies (Livieratoset al, 2017). For start-ups, these programs represent quick access to the markets and knowledge networks. This led to the creation of private incubators with a focus on creating new businesses, in an accelerated way (Grimaldi&Grandi, 2005; Becker&Gaassman, 2006)

Starting in 2010, nine of the ten largest companies in the European electricity sector have structured initiatives to promote start-ups in the Corporate Venture Capital modality(Livieratos et al, 2017). The role of venture capital in the electricity sector is to provide financing for high-risk, innovative research that can lead to the development of market effective start-up companies, as well as profitable and efficient technological solutions for the energy sector (Moore&Wustenhagen, 2004).

In Brazil, large companies in other segments of the service sector, such as the information and communication technology sector, have been implementing strategies of engagement and promotion of start-ups(Gelwan, 2015).In the electricity sector, start-up programs started to be developed in 2016. Currently, six Brazilian electricity sector companies started developing initiatives to support start-ups, inspired by an open innovation approach: CPFL Energia S.A.; EDP Brasil S.A; AES S.A.; Enel Brasil S.A.; *Companhia Energética de Minas Gerais* S.A. (CEMIG); and *Companhia Paranaense de Energia* S.A. (COPEL) (Lima et al, 2018). Studiyng the results of these initiatives we can better understand the benefits of the program to promote innovation in the electricity sector.

Because, as shown in this section, electricity companies and start-ups can cooperate with each other through these partnerships, the biggest challenge for the consolidation of start-ups lies in creating a network of relations with other actors that may help and support these nascent companies (Baraldi et al, 2018).On the other hand, large network companies want this relationship, wherestart-upsmay play a crucial role in assuming risks and grabbing opportunities for technological development, as they are more disposed at assuming risks than larger established companies (Spenderet al, 2016; Aaboen et al, 2013). And finally, since large companies in the sector will need to be increasingly aware of aspects such as security, accessibility and sustainability, they will progressively seek to operate and collaborate with other actors, such as start-ups, to find and develop innovative solutions

In fact, there are several examples of technological devices developed by start-ups that contribute to incremental innovations in the electricity sector, such as applications to facilitate energy exchange among prosumers (Rutkin, 2016), conversion and plug-in systems for electric cars, smart devices for the electricity networks (Electronics Weekly, 2011), among others. In the next section we start

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to study the challenges and improvements on the Brazilian sector.

This section investigated the role that start-ups may have in the development of innovations in the companies of the service sector. It also presents a discussion about their contribution to a transforming electricity sector, since large companies in the sector will need to be increasingly aware of aspects such as security, accessibility and sustainability. To do this, they will progressively seek to operate and collaborate with other actors, such as start-ups, to find and develop innovative solutions.

IV. METHODOLOGY

In order to discuss and characterize the innovation process in the Brazilian electricity sector companies, this article is structured in three parts. The first part (section 2) of this research consisted of a literature review on the concept of service innovation based on books and scientific articles.The scope of this search included the most cited studies of Google Scholar and Plataforma Sucupira[1] on the field of Service Innovation, as well relevant studies from recent decades. This section aimed to create the basis for the discussions on innovation strategies in Brazilian electricity sector companies, start-up programs and innovation surveys. The second part (section three) consisted of analysing the contributions of the specialized scientific and technical literature regarding possible benefits start-ups to innovation in the service sector, in order to identify implications that start-ups could have in R&D strategies of electricity sector companies.For this, a literature review from the electricity sector and regarding the relationships between companies, start-ups and networks was done.

The third part (section five) of this article seeks to analyse the innovation rates of the Brazilian electricity sector. For this purpose, primary and secondary data from the PINTEC[2]was used. The PINTEC is a Brazilian innovation survey carried out every three years – the last edition, published in 2020, spanned from 2015 to 2017 – to serve as a basis for the construction of innovation indicators regarding the innovation activities of national companies. According to Bernardes (2005), the recognition of the significance of the service sector for generating revenue and richness led to the production of innovation and R&D statistics in this sector in developed countries, as those of EUROSTAT. In addition, international statistical agencies such as Unesco and Unctad are measuring the innovation process in the service sector.

In Brazil, according to thesesame authors, the production of information on service innovation is still incipient, and the first efforts can be found in studies from SEADE Foundation (PAEP) and, more recently, in the inclusion of some service classes in the Innovation Survey of the *Instituto Brasileiro de Geografia e Estatística* (Brazilian Institute of Geography and Statistics) (IBGE). From the 2014 survey onwards, the PINTEC presents the results for industrial sectors (extraction and transformation) and selected service sectors separately. PINTEC also reports the electricity and gas sectors separately, which enables innovation trend analysis in the electrical sector.Data analysis was based on three categories: extractive and manufacturing sector, electricity and gas sector, and service sector in general. This division was done in order to map out innovation trends of the electricity sector *vis-à-vis* the industrial and services sector as a whole.

The Electricity and Gas sector - section D of the National Classification of Economic Activities (CNAE) 1 - is composed of three groups: (i) generation, transmission, and distribution of electricity (CNAE 351); (ii) production and distribution of gaseous fuels through urban networks (CNAE 352); and (iii) production and distribution of steam, hot water and air conditioning (CNAE 353). Companies with 500 or more employees were included in their totality in the survey. Another important characteristic is that the sample size was scaled to ensure that the estimator of people occupied in each stratum had a variation coefficient of 12% and had a loss rate of 15%. Based on a 15% loss rate at the end of the survey, 84 companies were effectively researched, representing a universe of 468 companies in Brazil. Among the 84 companies surveyed in the three categories of CNAE presented, 78 were from CNAE 351; 5 were from CNAE 352; and one from CNAE 353. Therefore, it can be stated that the data referring to the research developed by PINTEC is a good proxy of the electricity sector, since it corresponds to approximately 93% of CNAE's section D.

V. INNOVATION IN THE BRAZILIAN ELECTRICITY SECTOR

The electricity industry basically consists of power generation plants located across the country and of energy transmission and distribution lines that form the so-called

[1] Plataforma Sucupira is a platform used to collect information, carry out analyzes and evaluations, as well as being the reference base for the Brazilian National Graduate System (SNPG).

[2] PINTEC definition and survey. Availabe in: https://www.ibge.gov.br/estatisticas/multidominio/ciencia-tecnologia-e-inovacao/9141-pesquisa-de-inovacao.html?=&t=o-que-e Access: 02/04/2020.

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"network industry". As all consumed energy must be instantaneously produced, the whole system is connected (ABRADEE, 2016). Due to such features referring to product intangibility, instantaneous production and consumption, and dependence on a physical network, as discussed previously, the electricity sector may be classified - especially its distribution segment - as a sector that consists of *network services* (Metcalfe; Miles, 1997). As they are utility services, their efficiency is associated with access and quality of the delivered product and to uninterrupted availability.

The Brazilian federal government has already begun to implement actions to change electricity generation in the country in the next years, with initiatives such as the simplification of rules for energy generation in homes and commercial buildings; a change in the taxation of produced energy; and an industrial investment stimulus in the sector, with reductions both in the import tax of photovoltaic modules to supply the internal market and in export taxes (Dantas; Pompermayer, 2018).

The Brazilian federal government is responsible for policies concerning the electricity sector and its regulation. Companies are responsible for production, transportation and energy commercialization. The energy generation and commercialization segments may be characterised as competitive segments, due to the existence of many enterprises and also the fact that their product (electrical energy) is homogeneous. The segments that provide energy transportation (transmission and distribution) are natural monopolies: due to their physical structure, competition between two agents in a same concession area is not economically viable. The price regulation model or regulation by incentives predominates in these two segments. Thus, companies operate in a context of concession contracts, managed by the Brazilian Electricity Regulatory Agency (ANEEL) (ABRADEE, 2016).

The Brazilian electricity sector R&D Program coordinated by ANEEL, which aims to promote innovation development and was structured tohelp companies overcome technological challenges, will be analysed. This program obliges electricity sector concessionaires of the distribution, transmission and generation segments to annually invest a percentage of their net operational revenue (NOR)in R&D projects. According to the available data, this program mobilised approximately US$ 1,55 billion[3] between 2000 and 2017in 4,400 R&D projects, revealing a great success in mobilising resources (Castro et al, 2018).

[3] R$ 8,1 billion reais: exchange rate of commercial dollar, 31 of July of 2020.

A study conducted in 2011 (Figueiredoet al, 2011)indicates that researchers engaged in projects linked to ANEEL's R&D program developed significant scientific and technological production due to the project's development model. The projects carried out within the scope of ANEEL's R&D program are usually developed with other actors, organizations and institutions, such as research institutes, supplier companies, universities and even start-ups.

The statistics of the PINTEC research may be used to analyse results from ANEEL's R&D program and innovation in the electricity sector in general. This survey makes it possible to identify the main results achieved and how these results contributed (or not) to the electricity sector transformation.

According to the PINTEC data for the 2015-2017 period, in a universe composed of 116,962 companies with 10 or more employed staff in the country in all segments,39,329 implemented novel or significantly improved products and/or processes, which corresponds to a general innovation rate of33,6%.

Graph 1presents the distribution of companies by type of innovation, that is product, process, or marketing and organisational innovations. The same company can conduct more than one type of innovation.Thus, it is possible to verify that 28,44% of the electricity and gas companies, of a total of 594 companies, declared that they had developed product and process innovations in this period.The electricity and natural gas sectors have lower innovation rates than the service and industrial sectors. Previous PINTEC surveys all pointed to this tendency of the electricity sector to having lower innovation rates than other sectors. In comparison with the previous PINTEC survey, that encompassed the period from 2012 to 2014, there was a decrease in the innovation rate, which was 35%. This decrease may be related to the period of economic and political crisis in Brazil from 2015 to 2017, as the other sectors also had an expressive decrease.In 2017, Brazil continued to feel the effects of the recession, which helps to explain the reduction in the rate of innovation and the level of R&D investments in the Brazilian economy in this period. In times of crisis, company investment in innovation is often not seen as a priority. The reduction in the role of public policies for innovation is evident in the percentage of innovative companies that received some kind of public support to innovate. This is the result of the reduction of various public policies. In 2014, for example, the amount disbursed inform of credit for innovation activities by the Funding Authority for Studies and Projects (FINEP) and by the Brazilian Development Bank (BNDES) totaled

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around R$ 8 billion, but in 2017 the total amount was around R$ 4.3 billion. Furthermore, many of FINEP's instruments for innovation promotion virtually disappeared in 2017 (De Negri et al, 2020).

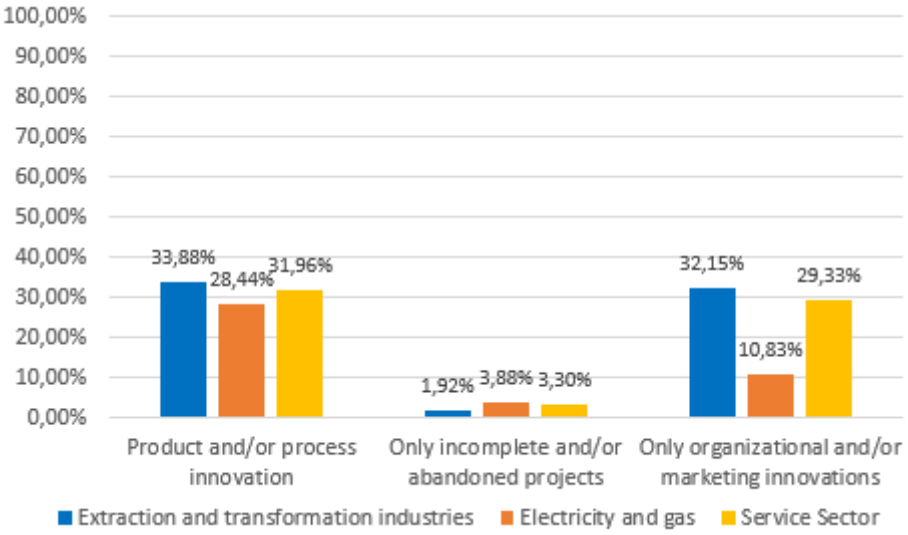

Fig.1: Brazil: Percentage of companies that conducted product, process, and organisational innovation by activity sectors, 2015-2017

Source: Authors, based on IBGE (2020)

The reports of the previous survey editions showed that process innovations always predominated when compared to product innovations. Process innovations declared to the PINTEC survey are mainly introduction of new or substantially improved methods for production, new methods to implement internal logistics of inputs and products, and increments in production service activities. In the service sector, innovation involved changes in equipment or software.

When only product and process innovations are considered, it is possible to validate the studies previously cited in this article that indicate that product and process innovation in the service sector, especially in the Electricity and Gas Sector, depends on cooperation. Graph 2indicates that product innovation is mainly developed by companies. However, it is possible to observe that, among other sectors, the electricity sector presents the lowest development rate of product innovations within a particular company. In the electricity sector, the development of innovations by other companies or through cooperation corresponds to more than half of the total.

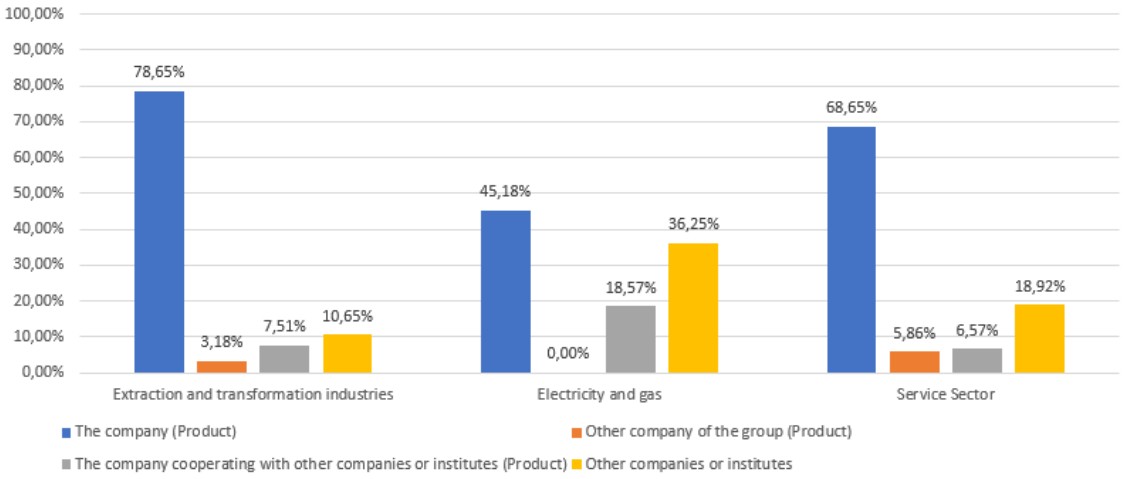

Fig.2: Brazil: Percentage of companies that developed product innovationsby sector, 2015-2017

Source: Authors, based on IBGE (2020)

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Graph 3 indicates that cooperation is important for process innovation in the electricity sector, as companies may individually have difficulties to reunite all competences needed to implement innovation. Regarding process innovation, the percentage of companies that develop innovations in cooperation with other companies or institutes is more than four times higher than the percentage verified in the service sector and in the sector of extraction and transformation industries.

Electricity sector companies have higher rates of product and process innovation in partnership with other companies due to the fact that the sector is more intensive in external R&D acquisition and also due to ANEEL's R&D program, which obliges companies to invest in innovative projects with other actors of the ecosystem such as suppliers and universities.

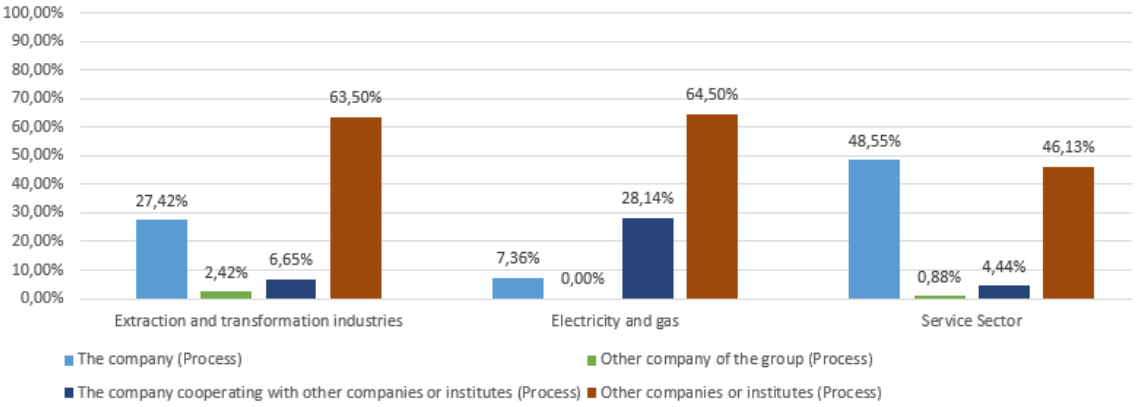

Fig.3: Brazil: Percentage of companies that developed process innovations by sector, 2015-2017

Source: Authors, based on IBGE (2020)

Referring to the direct and indirect impacts of innovations on the competitive capacity of companies, they were considered as being more relevant to maintain market participation than to increase market participation. In the electricity and gas sector, the main impacts for companies in relation to the implementation of innovation were the increased productive capacity (54,78%), reduced environmental impact and/or health and safety impacts (53,78%), and reduced production costs (51,28%); and the main obstacle for companies to conduct innovation, or reason for not innovating, were the high costs for developing innovations(78,58%). This result suggests that the increase in competitiveness caused by innovations was more related to a predominantly defensive strategy, intended to maintain the company's position in the market, even though there were specific objectives of increasing productivity and added value (IBGE, 2014).

In the electricity sector, regulation in service provision may intensify the adoption of defensive and conservative strategies. However, most companies (65,81%) in this sector also stressed that organisational rigidity was an obstacle for innovation. Electricity sector companies are large public companies or concessionaries that operate in a strongly regulated market. In this context, transaction costs related to terms for authorisations, evaluations, and approvals of ANEEL's R&D program create rigidity in companies and also in their operational environment. This happens because there may be differences between regulation business timing: when the transformations in the sector are fast, the stockholders may decide that companies must abandon outdated themes, but the company is obliged to continue with them in order to comply with regulation and to meet the requirements of the R&D program. Thus, there can be a mismatch between regulation and achievement of economic results.

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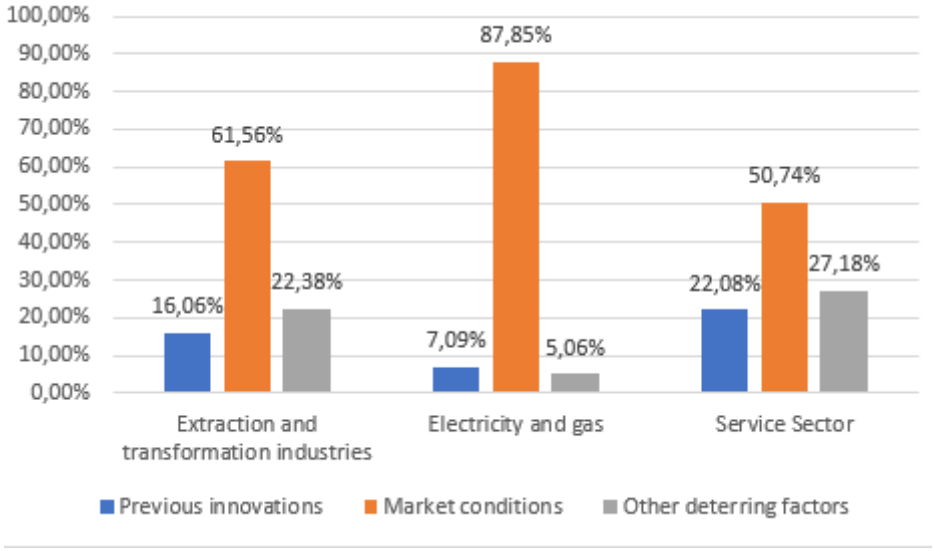

Fig.4: Brazil: Main reasons for not innovating, 2015-2017

Source: Authors, based on IBGE (2020)

All PINTEC editions indicate that, in Brazil, innovations result more from other innovative activities than from the company's internal R&D efforts. Examples of activities developed by companies include lesser novelty degree activities, training activities, new marketing or organisational methods, or the acquisition of external knowledge or capital goods that are not part of R&D. In the 2017 edition, this pattern repeated itself once again, with significant participation of innovations associated to "machinery and equipment purchase" (65,3%), "software purchase" (62,4%), and "training" (49,7%) in the electricity sector. External acquisition of R&D was one of the most significant innovative activities in the electricity sector (65,17%), although in the services and industry sectors it ranked the lowest innovation amongst all other activities.

Graph 5 presents the distribution of companies according to the degree of significance that companies attributed to their main product innovations. Product innovations in the electricity sector are more focused on product improvements that already exist in the company.

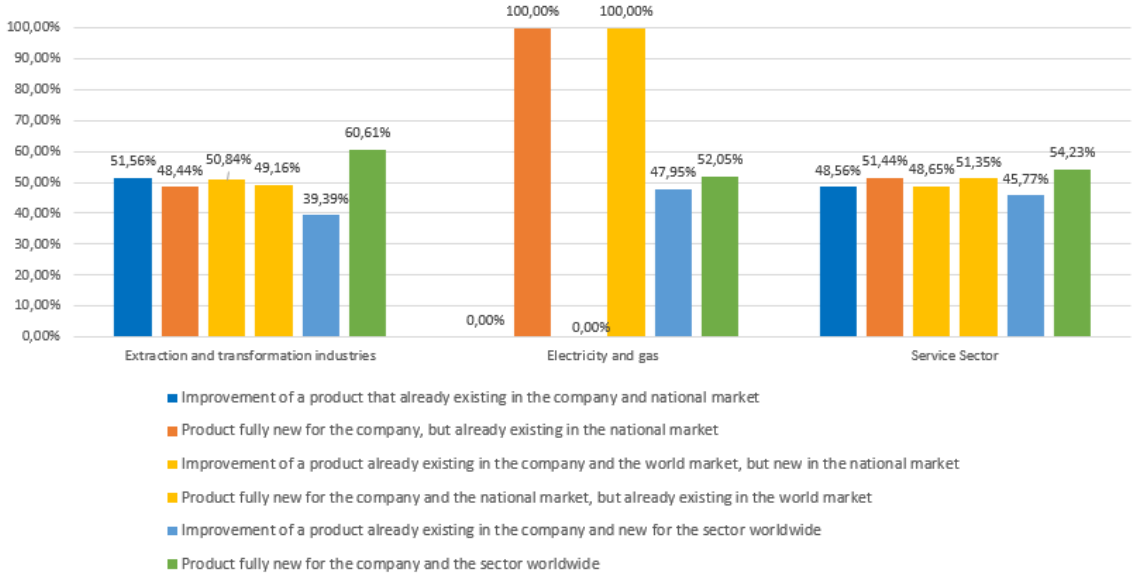

Fig.5: Brazil: distribution of companies according to the novelty degree of the main product, 2015-2017

Source: Authors, based on IBGE (2020)

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Graph 6 presents the distribution of companies according to the degree of significance that companies attributed to their main process innovations. Process innovations in the electricity sector are developed both for company improvement and to adapt the companies to the changes that take place in the national sector or that respond to global demands.

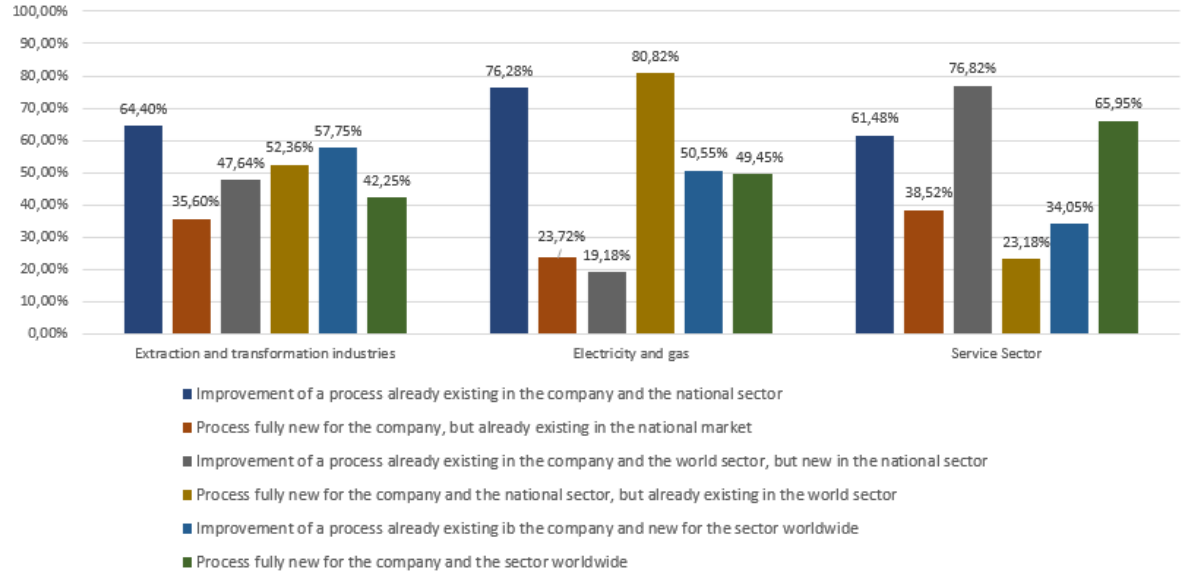

Fig.6: Brazil: distribution of companies according to the novelty degree of the main process, 2015-2017

Source: Authors, based on IBGE (2020)

PINTEC also provides data on marketing and organisational innovations because the survey considers that the concepts of product and process innovation are not sufficient to discern other significant elements of the innovative activities that compose the complex innovation processes(IBGE, 2016). Therefore, Graph7 presents organisational and marketing innovations in all sectors. In this case, the electricity follows the same trend as other sectors and has more innovations related to management techniques and work organization. However, unlike other sectors, it has lower levels of innovations related to design and marketing.

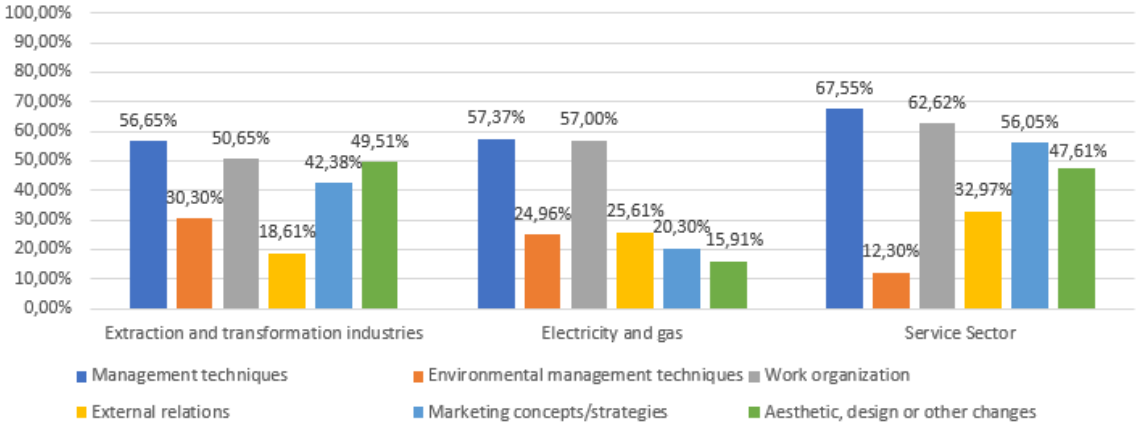

Fig.7: Brazil: Percentage of organisational and marketing innovations by sector– 2015-2017

Source: Authors, based on IBGE (2020)

Finally, based on information related to the specificities of the innovation process in the service sector and with the results from the PINTEC survey on the innovative profile of the electricity and gas sector, we can infer some conclusions about the standard of service innovation in the electricity sector: (i) technological innovation is mainly

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focused on processes and depends less on internal R&D activities and more on other innovative activities, such as development through cooperation; (ii) there are expressive efforts in non-technological innovations, that emphasize organisational changes and aim to improve companies by reducing their administrative or transaction costs, collaborating to improve access and understanding of non-codified external knowledge. Such efforts are focused on work organisation and human resources training.

The technological management strategy of the Brazilian electricity sector companies requires special attention to the capacity for setting more dynamic and flexible external relations that can decrease risks and rigidity in decisions concerning innovation. Currently, the strategy of several companies in the electricity sector consists of performing R&D in partnership with science and technology institutions or higher education institutions, ending the partnership once the project is completed. As noted by CGEE (2015), DISCOs do not have infrastructure to develop technological products, because such activity is not the focus of their business. In the current scenario of technological transformation in the sector, there may be an opportunity to foster new ways of organizing relations with other firms or public institutions according to new cooperation models. The establishment of new types of collaborations with research organisations or consumers, new methods for integration with suppliers, outsourcing activities, or the introduction of subcontracting are possible cooperation models (OECD, 2005).In such a context, the creation and acceleration of companies and start-ups represents an alternative to prepare electricity sector companies to the current dynamic business environment, especially in core themes of the sector. The United Nations Sustainable Development Goals for provision of clean energy and technological innovations in storage and generation are movements that are happening worldwide and are becoming a source of pressure for adjusting competitiveness, even if this only involves learning to use future innovations (Hak et al, 2016).

To sum up, PINTEC data points out that electricity companies are more dependent on external innovations than other companies surveyed. This opens opportunities for startups to provide services to electricity companies. As mentioned in this section 6 out of 75 Brazilian DISCOs (8%) have ongoing programs and initiatives to connect their businesses with startups.

VI. CONCLUSIONS

The current scenario indicates deep technological transformations in energy distribution activities, with an increase in distributed generation and the diffusion of energy storage. These transformations represent new challenges to companies, especially for companies in the distribution segment, which can lose part of their revenue. Furthermore, companies in the Brazilian electricity sector must ensure quality services every hour and day of the year and increase their consumer engagement.

The innovation strategy of companies in the Brazilian electricity sector enables them to improve their learning capacity and the absorption of existing technologies, which can lead to further developments in acquired technology and of new products and processes. Such process requires special attention to the changes in work organisation, because the learning process also brings about the possibility for companies to absorb workers tacit knowledge. Therefore, the social relations set among agents directly or indirectly responsible for innovation must be considered.

As pointed out in this article, electricity sector companies may be classified as network companies. Utility services, such as electricity sector companies, may be classified as network companies. Specialized literature suggests that service companies have a greater outward degree of innovation development, which reinforces the fact that consumers and suppliers are important for companies in these sectors. Furthermore, companies in the service sector use network relationships to gain access to a broad and versatile set of resources for innovation. In this sense, start-ups may play a key role in a company's networks to foster innovation in the electricity sector.

The literature presented in the first section of this article suggests that service companies have a larger outward degree of innovation development in comparison to inward innovation, which reinforces the fact that consumers and suppliers are important for companies in these sectors. This may be confirmed in the Brazilian electricity sector from the PINTEC data: 7,36% of companies developed process innovation inside their own company, while 64.5% of the companies carried out process innovation with other companies, institutes or partners. Regarding product innovation, the PINTEC data demonstrates that the electricity sector presents the highest development rate of this specific type of innovation with other companies in comparison to other sectors (service sector in general and extraction and transformation industries).

Companies in the Brazilian electricity sector tend to adopt mature technologies that have been already tested by the market, and, therefore, appear in the PINTEC survey as having relatively small innovation capacity in comparison to the other sectors analysed in the survey. These features

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reinforce the ongoing challenges for companies in the electricity sector posed by technological changes, especially in the distribution segment, as well as by adjustments in regulation regarding the provisions that aim to foster clean energy generation.

The PINTEC data indicates that there are also considerable efforts in non-technological innovations in companies of the Brazilian electricity sector (57,37% of the companies in the sector developed management techniques and 57% developed work organization innovations), that emphasize organisational changes and aim to improve companies by reducing their administrative or transaction costs, collaborating to enhance access and understanding of non-codified external knowledge.

In order to overcome the challenges of the current energy transition and the ongoing transformation of the electricity sector, the development of relational capabilities and cooperation will be even more significant activities for companies to develop innovations. Therefore, the development of partnerships with research and education institutions and the structuring ofstart-up support programs are strategic for companies in the sector. It should be noted that the establishment of such partnerships do not necessarily involve high investments in companies. These partnerships can also serve as a way of attracting qualified human resources for the development of new companies. As previously seen, dynamic sectors in the industrial sectorand in the service sector have already been adopting this model, and the participation of other companies in the innovation process is increasing. Companies in the service sector use network relationships to gain access to a broad and versatile set of resources for innovation. In this sense, start-ups may play a key role in a company's networks to foster innovation in the electricity sector.

Companies of the European electricity sector have been developing start-up support programs since 2010. In Brazil, this trend is relatively newer in the electricity sector (starting in 2016). Since market conditions are major barriers for companies to the innovate in the Brazilian electricity sector start-up programs may be an alternative to develop new and reconfigured solutions for companies in the sector at a relatively reduced cost.

As shown in this article, the way that innovations are developed by companies in the Brazilian electricity sector indicates the need for setting long-term partnerships to overcome their organisational rigidity and to foster innovation development. Start-up involvement in partnerships may provide interesting benefits for companies, such as access to complementary technologies and training, and the possibility for start-ups to act as intermediaries between energy distributors and prosumers. However, by analysing the PINTEC survey data presented in this article regarding cooperation, it is not possible to infer if partnerships established by companies are only set to purchase technology or whether there is effectively joint innovation development. Future research could be carried out by deepening the results of recent startup support programs in Brazilian electricity sector companies to analyze the impact of these initiatives in terms of innovation generation and diffusion.

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