CHAPTER 7

THE INNOVATION ECOSYSTEM IN THE BRAZILIAN ENERGY VALUE CHAIN

Robson Braga de Andrade, National Industry Confederation (CNI), Social Service for the Industry (SESI), and the Brazilian National Service for Industrial Training (SENAI)
Heloisa Menezes, Brazilian Micro and Small Business Support Service (Sebrae)

International agreements regarding climate change and the evolution of energy policies point to the increasing incorporation of innovation and the expanding use of renewable energy sources in the worldwide energy mix. The energy sector is going through a process of transition, in which its main challenge is to reduce the trade-off between the cost of energy and the preservation of environment.

Innovations in the energy sector have great disruptive potential. In the power sector, for example, the emergence of intelligent networks and the introduction of small-scale distributed generation have the potential to change the role and business models of distribution companies and present opportunities for small innovative businesses. The way energy is consumed, generated, and stored (or re-injected into the network) determines how the electric power network should be managed to guarantee security and sustainability of supply. The electric energy sector that will result from this process of technological change is likely to be quite distinct from the one we currently know.

Brazil has a strong tradition of innovation in the energy sector. The country experienced a shortage of coal and oil before the discovery of Brazilian oil in the 1990s. This history, along with the large size and significant diversity of the national energy sector, has imposed major technological challenges that have been addressed and overcome. Brazil has developed a complex and advanced innovation ecosystem in energy.

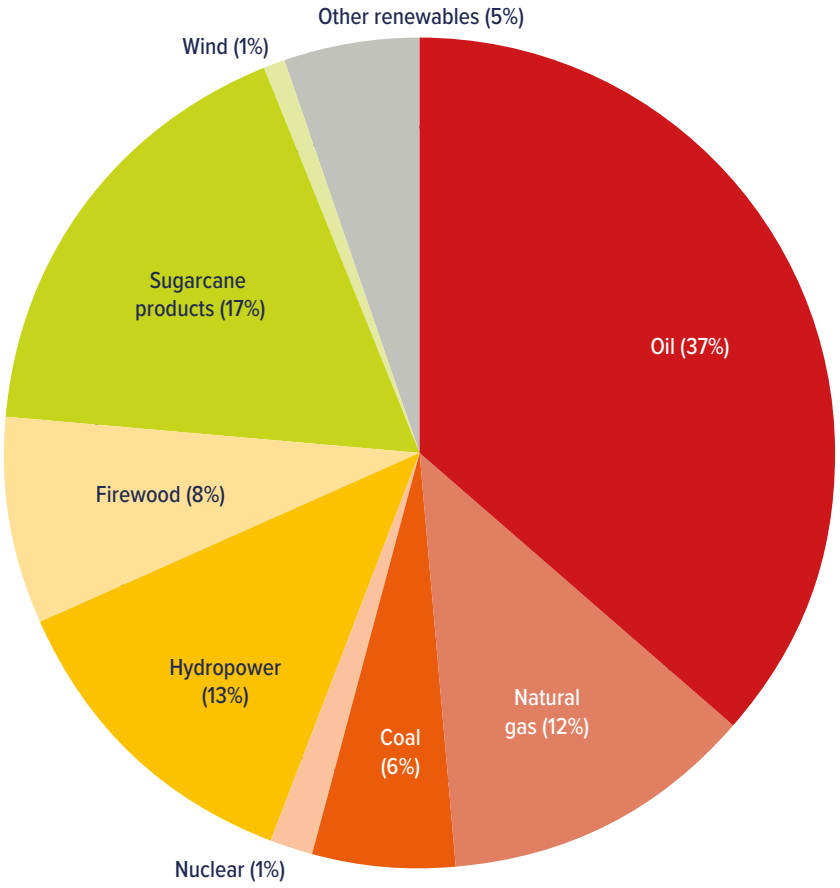
Despite its successful trajectory, new and old challenges must be tackled to ensure an ecosystem of innovation that is adapted to the global energy transition. This chapter seeks to present and discuss the Brazilian experience of innovation in the energy sector and point to the new challenges associated with the ongoing energy transition. The next section of the chapter discusses the main features and particulars of the Brazilian energy value chain; the following section considers elements of innovation in Brazil's energy sector; and the final section describes the main challenges that must be confronted to improve the sector´s innovation ecosystem, including the participation of small businesses.

The Brazilian energy value chain

The most distinctive feature of Brazil´s energy sector is the structure of its energy matrix. Brazil relies on important contributions from renewable energy sources in transport and electricity. In 2016 renewable energy met 43.5% of total energy consumption needs. The contribution of sugarcane energy products used for transport, electricity generation, and heat came to 17% of total energy supply. Hydropower dominates electricity generation, supplying 13% of the country´s energy. Oil plays a larger role in non-renewable sources, providing 37% of total energy.[1] Consumption of natural gas and coal are less prominent in Brazil than the global average. However, natural gas consumption is

Figure 1.

Brazilian energy matrix structure, 2016



Source: Source: EPE/MME, 2017a.

increasing rapidly in the country, and by 2016 was up to 12% (Figure 1).

Brazilian power generation is one of the cleanest of the world. Renewable sources reached 85% of installed generation capacity, totalling 160 gigawatts (GW).[2] Hydropower plants represent 71% of installed capacity. The country confronts the challenge of maintaining this high share of renewables in the context of growing demand and increasing difficulty in building new hydropower plants.[3] Thus other renewable sources (wind and solar) will need to compensate for the future reduction in hydropower participation in the energy matrix.[4] However, it is worth emphasizing that energy produced from solar and wind sources is intermittent and the growth of these sources will require the expansion of backup energy capabilities (such as gas-based thermal power plants, batteries, and other energy storage technologies). With the growing difficulty in constructing large dams with reservoirs, natural gas becomes an important option for ensuring the security of the energy supply.

The high penetration of biofuels in the transport energy mix is another important feature of the

Brazilian energy sector. Currently, ethanol and biodiesel represent 21% of energy consumption for transport in Brazil. The diffusion of biofuels in Brazil emerged as a response to the country's first oil crisis. In 1974, an ambitious programme to substitute gasoline with ethanol in light vehicles was launched (the ProÁlcool Programme).

The introduction of a bi-fuel vehicle in the 2000s re-launched the ethanol industry, offering consumers the possibility of choosing between gasoline and ethanol in gas stations.[5] Bi-fuel vehicles spread quickly and reached 94% of car sales and 65% of the car fleet in 2016.[6]

The addition of biodiesel to diesel began in December 2004, when the Brazilian government launched the National Program of Production and Use of Biodiesel (PNPB). In 2008, the government mandated a 2% biodiesel blend in mineral diesel fuel. The mandatory biodiesel mix percentage has gradually increased until reaching the current mandate of 10%.

It is worth noting that Brazilian energy policy is beginning to consider programmes that promote electric and hybrid vehicles. These vehicles have the potential to become a new technological paradigm in transport. The Brazilian experience with alternative engine technology can become an important driver of the innovation process necessary for the dissemination of this new paradigm.

In spite of its clean energy matrix, Brazil has made international commitments to fight global warming. In the Paris Agreement, Brazil committed to reduce its greenhouse gas emissions by 37% in 2025 and 43% in 2030, compared to its 2005 levels. For the energy sector, Brazil is aiming to increase its share of renewable energy to 45%.[7]

Regarding fossil fuel sources, Brazil's crude oil production has been growing rapidly in recent years as a result of the discoveries of prolific reserves in the pre-salt area.[8] However, a large proportion of the oil produced by this growth is exported, since domestic consumption is growing less quickly than production.

In 2017 average net exports of Brazilian crude oil reached 927,000 barrels per day. Because of restrictions in its refining capacity, Brazil imports large volumes of oil products: 350,000 barrels of oil equivalent per day in 2017. Thus the consolidated balance (crude oil plus oil products) comes to a daily net export of 577,000 barrels of oil equivalent. Brazilian oil production will keep growing in the next decade, with rapid increases in the surplus volume of oil to be exported.[9]

Innovations in the Brazilian energy supply chain

Innovation in the energy supply chain in Brazil was initiated by state-owned enterprises. When the electricity and oil sectors were liberalized in the 1990s, new innovation policies and tools were introduced. These emphasized innovation funds; clauses for mandatory investment in research, development, and innovation (RDI) in the exploration and production of oil contracts; and the legislation of mandatory RDI investment in the electric power sector.

Innovation in the power sector was originally initiated by Eletrobras, the sector's publically owned company. Eletrobras' objective was to promote domestic production and overcome the technological challenges of developing a hydropower-based sector. To face this challenge, Eletrobras created the Center for Research of the Electric Sector (CEPEL). With the liberalization of the power sector in the 1990s, electric utilities were obliged to invest 1% of their gross revenue in RDI and energy conservation projects. In addition, a fund to promote innovation in the power sector (CT-Energ) was established by the government.

Most RDI projects for utilities were developed in cooperation with universities and research centres. Between 2008 and 2015 approximately 2,400 projects were developed, and a total of 4.8 billion Brazilian reais (R$) were invested in these projects.[10]

In 2017 the National Agency of Electric Energy (ANEEL) completed a study, coordinated by the Centre of Management and Strategic Studies (CGEE), on technology prospecting in the power sector. This project mapped the RDI initiatives carried out in the power sector to determine whether the resources for RDI were properly used, aiming to improve innovation policies. The study found that 2,767 different research topics are being pursued in the Brazilian power sector. There are resources and laboratories available for innovation projects, although the country falls short in the terms of registered patents.[11]

In the oil and gas sector, the RDI clause in the area of lease contracts requires the investment of 1% of gross revenue from high-productivity oil fields into RDI. From 1998 until the second

quarter of 2017, oil operators spent more than R$12 billion on RDI. Petrobras was responsible for R$11.6 billion and other companies for R$832 million. More than 10,000 projects were contracted through the RDI clause in the oil and gas sector.[12]

In addition, the fund for Science and Technology for the Petroleum and Natural Gas (CT-Petro) was created by the Petroleum Law (Law 9478/97). This fund is financed partially by oil royalties;[13] it is under the administration of FINEP, the Brazilian Innovation Agency, and the National Council for Scientific and Technological Development (CNPq). Between 1998 and 2015, the resources collected by the fund reached R$16.2 billion. However, only 30% of the amount collected was included in the federal government budget for innovation and only 6% was effectively spent in RDI projects.[14] The rest was held back by the National Treasury.

The Inova Petro programme was created in 2015 as an alternative source of financing for technological innovation efforts, geared to meet the challenges of exploration and production imposed by the pre-salt discoveries. The focus of the programme is to encourage and promote domestic suppliers of technology.[15]

With respect to biofuels, the sectoral innovation system was created by the ProÁlcool Programme. This innovation system was traditionally structured around research centres, with projects focusing on sugarcane agriculture. With the recovery of the ethanol market in the 2000s, the aim of developing the capacity to produce second-generation ethanol (E2G) fostered greater involvement from governmental institutions. The Ministry of Agriculture launched the National Plan of Agroenergy (PNA), which led to the creation of the Embrapa Agroenergy research institution. Embrapa Agroenergy is focused on carrying out research for new varieties of sugarcane, including those suitable for E2G, as well as other possible raw materials such as sweet sorghum and forest residues. The Ministry of Science, Technology and Innovation (MCTI) promoted the creation of the Brazilian Bioethanol Science and Technology Laboratory and drew up specific actions for the biofuels sector within the Action Plan in Science, Technology and Innovation (PACTI).[16]

The year 2011 saw changes in the configuration of the sectoral system of innovation in biofuels, after which PAISS—a programme that supports innovation in biofuels and biochemical segments—was created. The programme was formulated jointly by the Brazilian National Economic and Social Development Bank (BNDES) and FINEP, and has two fronts: industry and agriculture. The objective of PAISS industry is to promote the development of innovations in three thematic areas: E2G, new products from sugarcane, and gasification. PAISS agriculture has the following research avenues: (1) new varieties; (2) machinery and equipment; (3) logistics and production; (4) propagation of seedlings; and (5) adaptation of industrial systems. Twenty-five research proposals were received for PAISS dedicated to industry and 35 for PAISS dedicated to agriculture. In total, the programme received R$5.2 billion in funding.

Finally, it is worth noting that technological cooperation and innovation networks represent an important dimension of the innovation ecosystem in the Brazilian energy sector. The National Confederation of Industry (CNI) and the Brazilian Micro and Small Business Support Service (Sebrae) play a fundamental role in the articulation of these innovation networks.

CNI stimulates research and innovation to promote the competitiveness of industry and of the Brazilian economy. Several actions implemented by CNI focus on the energy sector, including launching studies and cooperating with the government and congress to create policies to support the competitiveness of the Brazilian economy.[17]

The Brazilian National Service for Industrial Training (SENAI) Institute for Innovation in Renewable Energy and the SENAI Institute of Innovation in Biomass are important tools used by CNI to promote innovation in the energy sector. These two institutes work with the main stakeholders of the innovation ecosystem in the energy sector, aiming to facilitate financing and cooperation in RDI projects. Together these institutes have developed 30 RDI projects between 2014 and 2017, contributing to the increase in the country's industrial competitiveness.

The Business Mobilization for Innovation (MEI), in turn, considers that the bioeconomy can structure the economy for the future since it is directly linked to the invention, development, and use of biological processes and products in the areas of energy, health, agriculture, livestock, and industrial biotechnology. In October 2017 MEI's Dialogs seminar was dedicated to discussing this matter.

The project entitled 2027 Industry: Risks and Opportunities for Brazil in the Face of Disruptive Innovations, presented by the Euvaldo Lodi Institute (IEL) of CNI in cooperation with the Economics Institute of the Federal University

of Rio de Janeiro (UFRJ) and the University of Campinas (Unicamp), has identified electrochemical energy storage (rechargeable batteries, supercapacitors, cells, fuels, and hydrogen-based storage technologies) as one of the technological clusters with influence on the Brazilian industrial complex.[18] Industries such as aerospace, agrobusiness, automotive, and mining will experience a direct disruptive effect in the short (5 years) and medium term (10 years) through technological changes in power generation. These changes open niche opportunities in all related industries.

The Program for the Development and Qualification of Suppliers, an IEL initiative, contributes to increasing the competitiveness of the energy sector by encouraging interaction between large and medium-sized companies (anchor companies) and their suppliers. The objective is to promote the qualification of suppliers in several management areas, including innovation, as well as to foster networks of innovation and productive chains.

To encourage companies to innovate, CNI and Sebrae have published case studies of business innovation. Two of the three collections of case studies have included studies of innovative companies in the energy sector.

From 2004 to 2014, Sebrae and Petrobras worked together to develop small enterprises in order to promote their competitive inclusion in the oil and gas supply chain. Fifty-two projects were carried out in 16 Brazilian states, mobilizing local stakeholders through networks designed to promote cooperation and permanent interaction among companies and governmental, financial, and academic institutions, as well as other players in the oil and gas value chain. Out of the 18,000 companies that participated in the projects, 2,000 joined these networks.[19] Their primary goal was to open a space for small and medium-sized enterprises to innovate in a field dominated by large companies.[20] It is worth highlighting the successful experiments that brought about the inclusion of small companies into Petrobras' open innovation process with three different approaches, all of them beginning with a challenge proposed by the oil company. As a result, 12 technological solutions have been developed and made available in the market; around 22 are under development.

In 2017, Sebrae developed a new initiative with the Oil Industry National Organization (ONIP) in which large and medium-sized suppliers participate as anchors for innovation. These companies present their technological demands and opportunities to small innovative suppliers: more than 20 small businesses showed interest in developing projects in partnership with RDI institutions to meet the anchors' demands.[21]

Sebrae has participated in the design of policies to promote innovation and technological cooperation geared towards small businesses. More recently, it has begun to support start-ups (Sebrae Like a Boss, InovAtiva Brazil, and StartOut projects) and scale-ups.[22] Together with SENAI, it has launched public tenders to promote innovation in small businesses in order to meet challenges proposed by large companies. A similar partnership is being formed with the Brazilian Agency for Industrial Research and Innovation (Embrapii).[23]

Finally, Sebrae is bringing together small innovative companies and investment funds and planning to promote corporate venture initiatives in 2018. These experiences should contribute to improving the mechanisms for inserting small businesses into the innovation processes of large companies in the energy sector, thus fostering technological linkages.

Innovation challenges in the Brazilian energy value chain

The previous sections have shown that Brazil has an active ecosystem of innovation in the energy sector, incorporating initiatives intended to include small businesses into the open innovation process of large companies. In recent decades, the country has not only adopted energy technologies developed in the international market, but also has had a leading role in specific segments of the energy industry, such as offshore exploration in deep and ultra-deep waters,[24] as well as advanced biofuels production.

Despite the successful trajectory of Brazil's energy sector, new and old challenges must be tackled to ensure an ecosystem of innovation adapted to the energy transition scenario. The following challenges for innovation in the Brazilian energy sector must be met.

Establishing an industrial and technological policy, including a clear strategy for innovation

Industrial and technological policy assists in establishing visions and convergent strategies for innovation investment in the uncertain

environment of the energy transition scenario. A good policy must include mechanisms to stimulate investment and the diffusion of technologies with disruptive potential and must also promote the attractiveness of projects with high technological risk.

The full development of the energy potential in the pre-salt area, which is currently one of the main challenges of the national energy sector, will depend on the introduction of technological innovations that would help reduce extraction costs and increase the oil recovery factor. This challenge requires the intensification of technological efforts to give economic sustainability to the pre-salt reserves.[25]

Brazil has the potential to be a leader in the development of disruptive technologies in deep water exploration, particularly in the subsea segment.[26] To achieve this objective, it will be necessary to integrate and coordinate the various initiatives of innovation policy in the oil sector, in addition to the intensifying technological cooperation between oil companies and suppliers in the supply chain.

Coordinating public policies and innovation programmes

Once a clear industrial and technological policy has been defined, a path is opened for the coordination of public policies and sectoral innovation programmes. Government initiatives to support innovation in the energy sector have proliferated in recent decades. Evaluating existing programmes and promoting greater synergies and convergence of efforts to support innovation is crucial.

The currently available programmes of innovation support should be revised after considering their effectiveness. It is important to verify whether there are overlaps between programmes; whether there is proper articulation and coordination between them; and whether the financing instruments and conditions are adequate for the proposed objectives.[27] After revising the programmes, it will be important to monitor and evaluate them permanently, elaborating and implementing performance indicators. The study on technology prospection in the electricity sector coordinated by CGEE illustrates this type of initiative, which could be replicated on the oil and biofuel sectors.[28]

Stabilizing funding for national RDI policy

Providing funding for the national RDI policy represents an important challenge for Brazil, given its current fiscal constraints. There are currently three basic financing sources for innovation in the energy sector: (1) the RDI clauses in oil exploration and production contracts and the specific legislation for RDI for the electricity sector; (2) the national budget resources allocated to innovation funds (CTPetro and CT-Energ); and (3) the BNDES and FINEP resources for innovation in general and those allocated to Inova Petro. The funds of the RDI clauses are substantial and relatively stable, varying in accordance with the gross revenues of energy companies subject to those clauses. The national budget resources have historically been very unstable, depending on the fiscal policy of the moment. The availability of funding sources from BNDES faces fewer restrictions, while the resources from FINEP have been recently significantly reduced.

Funding stability is an important issue for innovation policy in the energy sector. The effectiveness of some programmes has been compromised by unpredictability and instability of financing. This is the case for the innovation funds (such as CTPetro and CT-Energ) that depend on national budget resources.

In this context, it is important to adjust the mandatory clauses of RDI investment of the oil and the electric power sectors to increase the efficiency of the investment. These adjustments should consider the possibility of (1) investments in suppliers' RDI projects, (2) reducing legal uncertainty, (3) promoting collaborative innovation projects, and (4) using private management for RDI projects to avoid the risk of projects budgetary discontinuity.

Promoting technology cooperation and including small and medium-sized enterprises in the innovation ecosystem

The Brazilian energy industry is undergoing an important transformation with a reduction of the state company's role. Moreover, the current technological context of the energy sector is riskier now because of the diffusion of disruptive technologies. Thus technological cooperation has an important strategic position in a successful innovation ecosystem.

It is worth stressing the importance of including innovative small and medium-sized enterprises in the innovation ecosystem. The initiatives of technological cooperation promoted by CNI, Social Service for the Industry (SESI), SENAI, and Sebrae can be powerful tools to boost the linkage effects of technological innovation in the energy sector through the greater participation of small and medium-sized enterprises in this process.

It is crucial to include initiatives to insert small businesses into the sectoral innovation ecosystem, both in the implementation and in the periodic review of programmes to support innovation in the energy sector. Several new tools could be contemplated, including seed capital funds, venture capital, and corporate venture. Those tools may incorporate small businesses, including start-ups and scale-ups, in the process of open innovation in large companies that operate in the energy sector.

The rules of the mandatory application of RDI resources in the energy sector can play an important role in the promotion of technological cooperation. It is essential to seek new mechanisms for the enhancement of collaborative projects between energy companies and small innovative businesses. In addition, the purchasing power of state-owned enterprises can be an important tool to promote technology from start-up and scale-up companies in a sector with a strong presence of state-owned companies.

The same applies to the innovation support programmes using national budget resources. It is crucial to have sophisticated policies and tools that support innovation to induce technological cooperation between energy companies and start-ups or scale-ups, as has been done by CNI, SESI, SENAI, and Sebrae.

Some initiatives in this direction would include efforts to:

- encourage the development of local innovation ecosystems for the production of knowledge and technology for the energy sector by means of technological linkage between large companies and their suppliers, including corporate venture actions, and with the support of technological institutions;

- reform the mandatory clauses of RDI's investment in the oil, gas, and electricity sectors, promoting greater effectiveness of private investment;

- promote technological linkages between large companies and small business innovators, among them start-ups and scale-ups, and stimulate venture capital for these companies, using the mandatory investment in RDI by large energy companies;

- prepare and encourage the presentation of innovative small businesses, start-ups, and scale-ups to national and foreign investment funds;

- encourage partnerships between all sizes of domestic and foreign companies interested in expanding their markets. These partnerships can be promoted through national and foreign financing of projects and programmes for technological cooperation with leading countries in innovation in the energy sector; and

- encourage partnerships between Brazilian and foreign technological institutions in innovation research projects.

The six points highlighted above would allow the Brazilian energy value chain to become more innovative and the Brazilian industry to become more competitive worldwide.

Notes

1 EPE/MME, 2017a.

2 EPE/MME, 2017a.

3 Stricter environmental restrictions and lower social acceptance is hindering new hydropower projects.

4 CNI, 2017a.

5 'Bi-fuel' or 'dual fuel' vehicles refer to vehicles with engines that can run on two fuels, such as gas and alcohol.

6 ANFAVEA, 2016.

7 CNI 2017b; EPE, 2016.

8 The discoveries by Petrobras and other companies in the province of the pre-salt layer, located in the Brazilian continental shelf, can mean reserves of over 50 billion barrels of oil. There may be large oil and natural gas reserves up to 200 kilometres wide located under salt layers that extend for 800 kilometres along the Brazilian coast, from Santa Catarina to Espírito Santo.

9 EPE/MME, 2017b.

10 CGEE, 2017.

11 CGEE, 2017.

12 ANP, 2017; Asrilhant, 2017.

13 The funding for CT-Petro corresponds to about 12% of the total collected from royalties.

14 Rocha, 2015.

15 BNDES, 2017.

16 Furtado, 2015.

17 Some of the published studies on the subject include *O financiamento do investimento em infraestrutura no Brasil. Uma agenda para sua expansão sustentada* (CNI, 2016a); *Oportunidades para a privatização da infraestrutura. O que fazer, como fazer* (CNI, 2017c); and *Energia nuclear. Questões para o debate no Brasil* (CNI, 2016b).

18 MEI, 2018.

19 Borges et al., 2014.

20 Petrobras, 2017.

21 Hasner et al., 2016.

22 Scale-ups are start-ups that are experiencing rapid growth as a result of the development of a scalable business model. More information can be found at https://www.inovativabrasil.com.br or http://www.sebrae.com.br/sites/Startup.

23 Embrapii is a research company connected to the Ministry of Science, Technology, Innovation and Communication.

24 Morais, 2013.

25 Almeida et al., 2017; Pinto, 2017.

26 This potential is justified by: (1) the technological requirements for the development of pre-salt; (2) the scale of demand for technological solutions in the sector, which places the country as a major consumer of subsea goods and services; and (3) the presence in the country of the world's leading players in this industry.

27 Almeida et al., 2017.

28 CGEE, 2017.

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