The biodiesel innovation system

Laura Rodrigues Alves Soares

Universidade Federal de Minas Gerais (UFMG)
Agência Nacional do Petróleo, Gás Natural e Biocombustíveis (ANP)

May 13, 2024

Abstract

Despite significant growth of the Brazilian biodiesel industry, the technological goals outlined by the government have largely not been met. This study employs an analytical framework based on the "Functions of Innovation Systems" by Hekkert *et al.* (1) to investigate the reasons behind technological stagnation, gathering novel data from multiple sources. The main findings include factors contributing to this stagnation: a decline in scientific and technological development in recent years, with limited innovation efforts from producers; underutilization of research networks and collaborations between universities and industry; poor technological development of engines adapted to biodiesel; and nascent diversification of raw materials.

Keywords: Biodiesel; Functions of Innovation System; Energy Transition Policy.

Trabalho executado com o apoio da ANP

Área temática: 1.ECONOMIA

Biodiesel was officially introduced into the Brazilian energy matrix in 2005 (2), after the National Program of Production and Use of Biodiesel (*Programa Nacional de Produção e Uso do Biodiesel*) (PNPB) was created. During that period, several goals for technological development were set for the whole biodiesel chain. Essentially, they were the following: to diversify raw materials used for biodiesel production, by increasing the use of low quality, lowering costs, and including regional cultures; to optimize production technologies; to develop finer techniques for quality control; to ensure the quality of biodiesel in storage; and to increase the value for co-products. The industry grew significantly, reaching a production peak of almost 7 million m^3 in 2021 (3), amounting to 12.6% of world's total production (4). However, since 2005, these technological goals were not met overall, and there were no significant innovations.

Since its implementation, the biodiesel industry in Brazil basically operates via the same technological route (detailed in Section 1). Although incremental innovations did occur, they are not sufficient to explain the decrease in the production costs observed in that industry between 2005 and 2015 by Nogueira *et al.* (5). The investigators sustain that this reduction is explained both by economies of scale and by a decrease in input rates (5), especially in soybean oil. Raw material costs account for around 80% of final production costs (6) and producing biodiesel from the soybeans is notably more profitable if compared to rapeseed and sunflower, for example (7).

Concerning the adoption of biodiesel, a niche market was created at the beginning of PNPB, by establishing a compulsory blend of biodiesel to all fossil diesels sold to final consumers in Brazil (2). The blend level, originally set at 2%, grew more rapidly than initially planned, reaching 13% in 2021. Fuel distributors are allowed to voluntarily increase the blend in any amount exceeding the mandatory minimum up to a maximum of 15% in volume, as long as engines pass tests and trials (8, p. 37). The biodiesel industry has never operated with a high utilization factor, having the structure for extra production. Nevertheless, voluntary use is very low (9), as biodiesel is usually more expensive than its fossil counterpart. Therefore, biodiesel production/consumption grows at the same rate as diesel consumption grows, subjected to the mandatory blend. Furthermore, no relevant modifications or adjustments were made to the diesel engine so it might have an improved performance with a higher amount of biodiesel.

In this article, we attempt to explain the failure to meet the technological goals for biodiesel technology in Brazil. The aim is to create insight into underlying factors associated with the operation of the biodiesel innovation system considering the framework from "Functions of Innovation Systems" (1),[1] data from Innovation Survey (*Pesquisa de Inovação*) (PINTEC), and a comparison with the ethanol innovation system. Results include a detailed understanding of the system and events which collaborated (or did not so) to successful innovation. Considering that the Brazilian government aims to enhance biodiesel blends and considers biodiesel an important technology to address climate change (11), the conclusions from this study can be fundamental to evaluate existing innovation policies and designing new ones.

[1] Nikas *et al.* (10) partially addressed the subject; however, its analysis was less comprehensive and based on incomplete data. Moreover, its approach differed somewhat from the current study.

1 Technical aspects

In the first half of the 20th century, several experiments were conducted in engines with different types of vegetable oil and animal fat. However, their high kinematic viscosity restricted direct use. The main technological route to convert oil and fats into biodiesel is via transesterification, which is a well-known (12), simple, relatively inexpensive, and easily operable process. The biodiesel industry in Brazil operates with this process.

Industrial equipment for biodiesel production via continuous transesterification processes is available in Brazil from national manufactures. Dedini S.A., a company founded in the 1920s in São Paulo and a supplier of capital goods for ethanol mills and distilleries (13), also provides full biodiesel plants. Dedini (14) states that its equipment features "simple mechanics, easy maintenance, and high efficiency" and reports having already installed 6 plants with a capacity of 630,000 m³/year and 5 plants with a capacity of 675,000 m³/year, all of which are operational.

Despite its simplicity and widespread use, the conventional transesterification reaction encounters operational challenges. It is notably sensitive to moisture but also to the free fatty acid content in the oil. High levels of free fatty acids result in the formation of soap, reducing yield and complicating the separation and purification process. Additionally, mass transfer limitations arise due to the immiscibility of oil and alcohol.

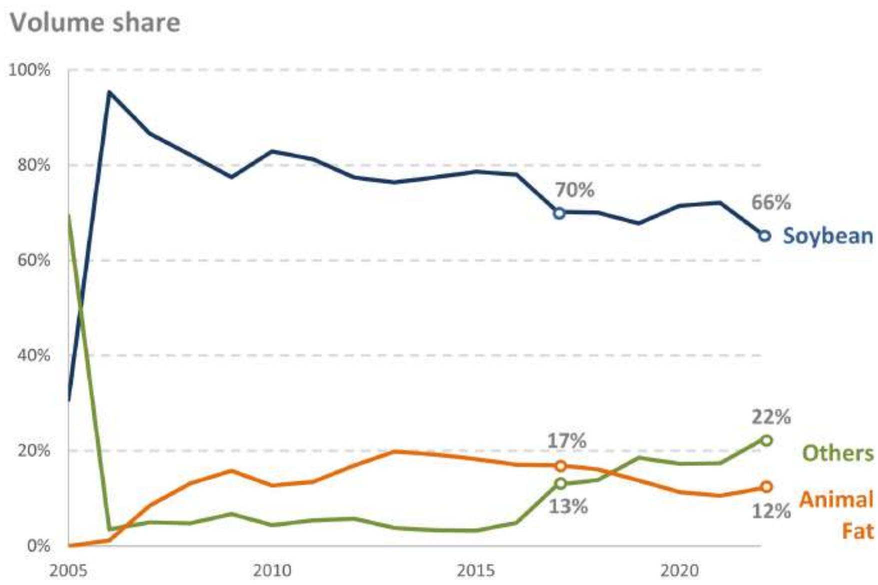
When evaluating vegetable oils and animal fats for transesterification, their quality needs to be considered. As previously mentioned, the transesterification reaction performs best with low-acidity feedstock, which are typically more costly (6). Finally, the production scale of feedstock poses a significant challenge for industrial production. In Brazil, despite the goal for raw material diversification, alternative vegetable oils are not available to supply the biodiesel industry on a scale that is compatible with demand (6). Unlike more accessible raw materials, such as rapeseed and sunflower, producing biodiesel from soybeans in Brazil is notably more profitable (7).

The most commonly employed triglycerides to produce biodiesel in Brazil are soybean oil and animal fat, accounting for 66% and 12%, respectively, in 2022. The rise in alternative raw materials observed from 2016 onward (Figure 1) cannot be attributed to diversification. In fact, most components in the "other" category are "other fatty materials", which are waste generated during biodiesel production and re-utilized. Therefore, the shift lies in the consequence of the developing a circular economy in production plants, rather than substituting soybean (8).

The significant availability of soybean grain, and consequently soybean oil for biodiesel production, stems from modernization of Brazilian agriculture since the 1960s, a process whose best representative is soybean (15). This modernization is reflected in a significant increase in productivity across all crops. Specifically, soybean land productivity increased by 3.5 times between 1970 and 2015 (15, p. 73).

Regarding biodiesel quality, the requirements outlined by ANP (16) closely align with North American standards (17). Regarding engine performance, comparisons between biodiesel and diesel as fuels in modern test engines demonstrate comparable performances (18). Overall, empirical findings suggest that biodiesel can be utilized without requiring any modification to the engine. Nevertheless, there is significant potential for improvement.

Figure 1 – Volume share of raw materials to produce biodiesel (2005-2022)



Source: created by the author, based on production data from ANP.

A study conducted by Indian researchers Goel; Kumar; Singh (19) aimed to evaluate the effects of different modifications made to diesel engines to optimize their performance when operating with biodiesel in terms of combustion, emissions, and overall efficiency. The findings suggest that increasing compression ratios, injection pressures, and optimizing injection timing result in improvements combustion, emission, and performance. These results indicate that even modest adjustments enhance engine performance with biodiesel.

2 Innovation systems

The central idea behind the concept of a "national system of innovation" is that successful innovations, their rate of diffusion, and their associated productivity gains are not simply related to R&D intensity, but also, and maybe more importantly, to other social and institutional changes (20). In other words, innovation creation and diffusion happens within a systemic process. Freeman (21, p.1) defined the "national system of innovation" as "the network of institutions in the public and private sectors whose activities and interactions initiate, import, modify and diffuse new technologies".

The concept of "technological system", introduced by Carlsson; Stankiewicz (22), while supporting the systemic importance for innovation production and diffusion, proposes a different approach. According to the authors, a technological system "may be defined as a network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology. Technological systems are defined in terms of knowledge/competence flows rather than flows of ordinary goods and services" (22, p. 111). Consequently, technological systems are industry-specific instead of referring to the economy as a whole, i.e., the proper level of analysis should be a technology or product, not an entire country. In this sense, boundaries are not necessarily national ones;

they can be either a region within a country or internationally spread. Moreover, the technological system approach focuses on the adoption and use of one technology rather than the generation and distribution of knowledge (22).

The concept of functions was established by Johnson (23) as the outcome of an extensive review of existing system approaches concerning "what happens in an innovation system". Function is defined as "the contribution of a component or a set of components to the goal [of the innovation system]" (23, p. 2), being that goal "to develop, diffuse and utilize innovations" (23, p. 4). The concept of function is useful not only to describe the present state of a system but also to assess its dynamics, how it emerges and shifts. Furthermore, studying the functions allows for the assessment of an innovation system's performance – for example, by analyzing its "functionality", i.e., how well its functions have been served (23, p. 17).

Hekkert *et al.* (1) labeled Carlsson; Stankiewicz (22)'s technological systems as technology specific innovation systems (TSIS), departing from a specific technology. Then, the authors presented a framework for mapping what they considered the central seven TSIS functions (further discussed in section 3.1). The idea is that the analysis of technological changes should focus on systematic mapping of key activities in TSIS to explain shifts. Changes may happen faster when functions interact and lead to virtuous cycles.

When applied, the functions approach maps the relevant "events" identified in the technology-specific innovation systems. These "events" are then allocated to each of the seven functions and represented over time. The method enables the visualization of periods when each function performed well and when it did not. Finally, the seven pictures are to be analyzed concurrently to construe a full picture of the system functioning (1). Among the reasons to adopt this approach is reaching a potential set of policy goals as well as instruments to meet those goals.

The functions approach, both the one developed by Hekkert *et al.* (1) and the one by Bergek *et al.* (24), formed the framework for an extensive amount of papers, mainly related to sustainable innovation, including alternative transport fuels and renewable energy technologies, as pointed out by an extensive review carried out by Bergek (25). One of her key findings was that that same framework had been applied to innovation systems in underdeveloped countries, in a different context from the one in which it was first developed. She claims that these economies "are more fragmented and lack an established knowledge infrastructure and that they are more context-dependent but also more dependent on developments at the local level" (25, p. 16). For Brazilian systems, the framework was applied in the sugarcane and biofuel sector before the Proálcool (26); likewise, it was applied to the production of ethanol (27, 28), biogas (29), second-generation ethanol (30), and solar photovoltaic systems (31).

3 Methodology

3.1 Functions of the innovation system

The seven system functions proposed by Hekkert *et al.* (1) are listed below.

1. Entrepreneurial activities: entrepreneurs can be either new entrants or incumbent companies who diversify their business strategy. The presence of entrepreneurs is the most important indicator of innovation system performance (1, p. 422).

2. Knowledge development (learning): learning lies at the core of any innovation (32, p. 927).

3. Knowledge diffusion through networks: the aim is to identify knowledge flows, considering that the essential function of a network is to exchange knowledge (22).

4. Guidance of the search: it refers to mechanisms that influence the direction taken by firms and other actors as they look for new opportunities and select problems and solutions to which they dedicate their resources (25).

5. Market formation: as new technologies face challenges in competing with embedded technologies and undoing existing lock-ins, it is paramount to create protected spaces for them to thrive during their initial stages (32).

6. Resource mobilization: allocating sufficient resources is required to enable knowledge production (1).

7. Support from advocacy coalitions: if a new technology should succeed, it would become part of an incumbent regime or it would have to overthrow it, unavoidably facing opposition. Advocacy coalitions can lobby for resources, and favorable market conditions (1, 32).

To map the functions' activities over time, the indicators shown in Table 1 were evaluated. The indicators for entrepreneurial activities are the same as those used by Negro; Hekkert; Smits (32) and Furtado (33); so are the cases for: guidance of the search and market formation. Knowledge development and resource mobilization were interpreted following Furtado (33), with additional information from PINTEC to account for the share of innovators. To map knowledge diffusion, the metrics for conferences, workshops, and networks were used by Negro; Hekkert; Smits (32); joint publications and patents were accounted for by Furtado (33); and relative importance of external information for companies was evaluated using the results from PINTEC. Resource mobilization was mapped not only with public funding, as in Furtado (33) but also with R&D expenditure accessed with PINTEC. The support of advocacy coalitions was measured with the support in Congress, proposed as a new indicator.

3.2 Data from PINTEC

The Innovation Survey (*Pesquisa de Inovação*) (PINTEC) was conducted by the Brazilian Statistics Institute (*Instituto Brasileiro de Geografia e Estatística*) (IBGE) in 2011, 2014, and 2017, with the objective of measuring innovation activities within companies. Its results were presented grouped for the category "producers of coke, petroleum products, and biofuels".[2] To request for a special tabulation of the results exclusively for

[2] *Fabricação de coque, de produtos derivados do petróleo e de biocombustíveis*

Table 1 – Function indicators for the biodiesel innovation system

Function	Indicators	Sources
1. Entrepreneurial activities	-new entrants - diversyfing incumbents	- production per year data from ANP - companies websites - BiodieselBR website - Valor Econômico online newspaper
2. Knowledge development (learning)	- scientific publications - issued patents - share of innovators	- Scopus database - Brazilian Patent Office (INPI) database - PINTEC survey
3. Knowledge diffusion	- technological network - industry associations - conferences and workshops - joint scientific publications - joint patents - relative importance of external information for companies	- Scopus database - Brazilian Patent Office (INPI) database - Ministry for Science, Technology and Innovation (MCTI) - industry associations websites - BiodieselBR website - PINTEC survey
4. Guidance of the search	- sectorial policy - blend targets - standards and regulation	- Ministry for Science, Technology and Innovation (MCTI) - Ministry of Agriculture, Livestock and Supply (MAPA) - National Agency for Oil, Natural Gas and Biofuels (ANP)
5. Market formation	- niche market - commercialization models - tax benefits	- National Agency for Oil, Natural Gas and Biofuels (ANP) - National Council for Energy Policy (CNPE) - Brazilian Law
6. Resource mobilisation	- public funding for biodiesel producers - public funding for scientific research - R&D expenditures	- National Bank for Economic and Social Development (BNDES) - Scopus database - PINTEC survey
7. Support from advocacy coalitions	- support in the National Congress - support from public oppinion	- National Congress website - Folha de S. Paulo online newspaper

Source: created by the author.

biodiesel producers, we sent IBGE a list of the registration numbers[3] of companies that were authorized to operate by ANP at some point (Appendix 5). IBGE kindly provided the requested dataset, which was analyzed to map indicators for the functions learning (Section 4.2), knowledge diffusion (Section 4.3), and resource mobilization (Section 4.6).

4 Functional analysis

4.1 Entrepreneurial activities

Entrepreneurial activities in the Brazilian biodiesel sector were analyzed in two stages. The first stage accounts for openings and closings of biodiesel plants in the period between 2005 and 2022. Neither fusions nor acquisitions were considered openings, nor intermittent operations – when a plant shuts down but reopens up to three years afterwards – were considered openings or closings. Since entrepreneurs are both new entrants that see opportunities in new markets or incumbent companies who diversify their business to take advantage of new developments (32), all remaining openings and closings of plants were tabulated in the data shown in Figures 2 and 3. By observing the data, three periods of entrepreneurial activities are identified.

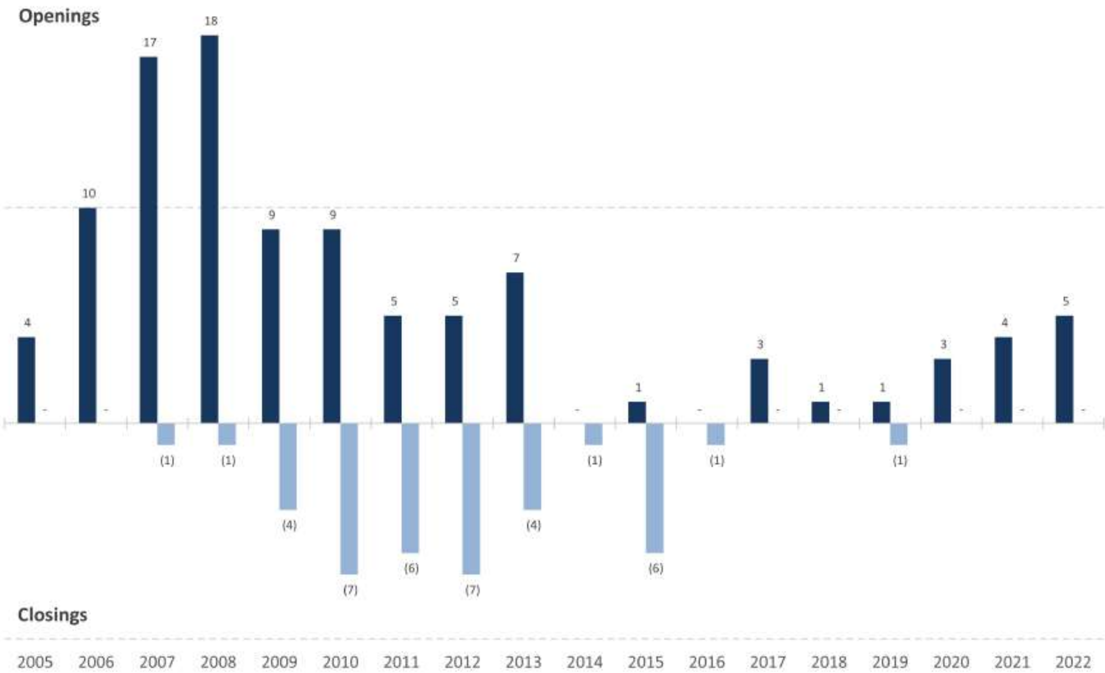
In the first period (2005-2008), there was a significant industry expansion with a growing number of openings and very few closings. The sector expanded tenfold: from 4 plants in 2005 to 42 in 2008, in the first year of the mandatory blend. In the second phase (2009-2016), despite an initial increase in operational plants – reaching its peak in 2010, with 54 plants –, an adjustment is identified with significant amounts not only of closings but of openings, as well. Entrepreneurial activity remained intense in this period, but at a slower pace than in the first one; from 2010 onward, the number of plants consistently diminished. During this adjustment period, in September/2013 ANP published a new resolution stating, clearly establishing authorization requirements for biodiesel plants (34). Finally, in the third phase (2017-2022), the industry expanded again, but, this time, at a much slower pace.

The second stage of analysis for entrepreneurial activities was the elaboration of company profiles. Data on the ten companies with the greatest production shares in 2022 (all above 3%) were gathered and displayed in Table 2. Four common features among the firms can be highlighted. Firstly, most companies are originally Brazilian (9 out of 10), suggesting little international interest in the national biodiesel sector. Secondly, most businesses (9 out of 10) operated in other sectors before entering the biodiesel market, predominantly soybean agribusinesses (six companies). Therefore, the sector was mainly composed of companies experienced in processing raw materials rather than companies focused on fuel production and distribution. Thirdly, most firms (8 out of 10) entered the industry in that first phase of activity (2005-2008), showing the importance of this early period for developing the sector. In fourth place, most firms (9 out of 10) expanded internally, opening new plants after the first.

Out of all the companies profiled, Be8 (former BSBIOS) seems to have a different approach to the business. The largest producer – with a production share of 14% in 2022 (Table 2) – was founded in 2005 with the aim of operating in the biodiesel sector. In 2007,

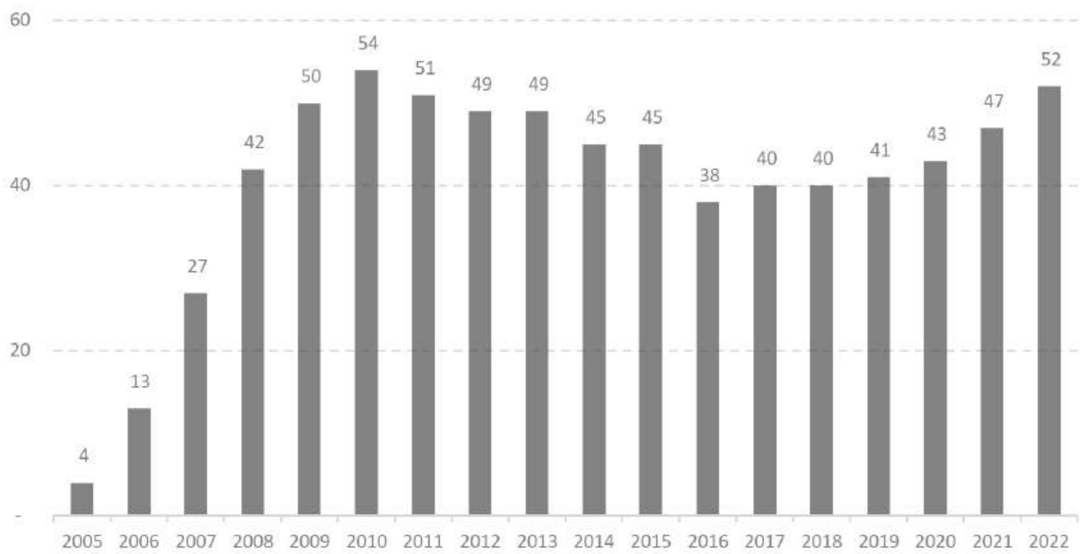
[3] CNPJ – *Cadastro Nacional da Pessoa Jurídica*.

Figure 2 – Openings and closings of biodiesel plants (2005-2022)



Source: created by the author, based on production data from ANP.

Figure 3 – Biodiesel plants in operation (2005-2022)



Source: created by the author, based on production data from ANP.

it established a network with Embrapa and other supporters to research alternative raw materials for biodiesel production, such as canola, sunflower and castor beans (35). Despite their initiative, most of the firm's current biodiesel production is derived from soybean (35). Recently, the company expanded operations to Switzerland and Paraguay and has been investing in other biofuels (48).

Table 2 – Biodiesel producers with the top ten greatest production shares in 2022

Company	Origin	Foundation	International biodiesel plants	Brazilian plants City (State) [start-up year] f. founding; a. acquisition; c. closing.	Production share (2022)	Original market
Be8 (former BSBIOS)	Brazil	2005	Switzerland Paraguay	Passo Fundo (Rio Grande do Sul) [f. 2007] Marialva (Paraná) [f. 2010]	14%	New
Olfar	Brazil	1988		Eremchim (Rio Grande do Sul) [f. 2010] Porto Real (Rio de Janeiro) [a. 2015] Porangatu (Goiás) [a. 2019]	10%	Soybean processing
Oleoplan	Brazil	1979		Veranópolis (Rio Grande do Sul) [f. 2007] Iraquara (Bahia) [a. 2012]* Tomé-Açu (Pará) [f. 2022] Cacoal (Rondônia) [f. 2022]	9%	Soybean processing
JBS	Brazil	1953		Lins (São Paulo) [f. 2007] Campo Verde (Mato Grosso) [a. 2015] Mafra (Santa Catarina) [f. 2021]	7%	Meat production
ADM (Archer Daniels Midland Company)	US	1902 (US) 1997 (Brazil)	US EU Canada	Rondonópolis (Mato Grosso) [f. 2007] Joçoaba (Santa Catarina) [f. 2013]	6%	Soybean processing (Brazil)
Potencial	Brazil	1954		Lapa (Paraná) [f. 2012]	6%	Fuel distributor
Caramuru	Brazil	1964		São Simão (Goiás) [f. 2007] Ipameri (Goiás) [f. 2010] Sorriso (Mato Grosso) [f. 2017]	6%	Soybean, corn, sunflower, canola processing
Binatural	Brazil	1984		Formosa (Goiás) [f. 2008] Simões Filho (Bahia) [f. 2021]	6%	[Grupo União] Brokerage of agricultural commodities, electrical energy generation, ethanol production
Granol	Brazil	1965		Anápolis (Goiás) [f. 2006] Cachoeira do Sul (Rio Grande do Sul) [f. 2008] Porto Nacional (Tocantins) [a. 2012]*	5%	Soybean processing
Petrobras	Brazil	1953		Candeias (Bahia) [f. 2008] Montes Claros (Minas Gerais) [f. 2009] Quixadá (Ceará) [f. 2008 / c. 2016]	3%	Oil production and refining

Sources: created by the author, based on production data from ANP; company official websites (35, 36, 37, 38, 39, 40, 41, 42, 43, 44); and BiodieselBR (45, 46, 47).
Notes: * Former V-Biodiesel, former Brasil Ecodiesel.
The remaining 26 firms in the market amount to less than 3% production share each.

4.2 Learning

Knowledge development, or learning processes, result in broader and more profound knowledge bases for a technological system (25). To assess the indicators, learning was split between scientific and technological knowledge, following the methodology by Furtado (33). Furthermore, the share of self-declared innovators was evaluated based on data from PINTEC.

4.2.1 Scientific knowledge

Scientific knowledge was mainly described in terms of published scientific documents. Despite a decreasing trend in the creation of scientific knowledge related to biodiesel in Brazil (Figure 4), the country still ranked fourth in the world in 2022, responsible for 4.6% of total publications, behind India (21.6%), China (10.4%), and Malaysia

(5.1%), but ahead of the United States (3.2%). In Brazil, scientific interest in biodiesel became relevant after the compulsory blend for fossil diesel was implemented, as shown in Figure 5. Afterwards, the number of publications grew to a peak of 391 in 2017. Interest, then, decreased in 2022 to 2011 levels.

Among the top ten Brazilian institutions to which the researchers are affiliated, nine are universities (Figure 6). Embrapa is the last organization in the top ten and Petrobras ranks #20 among Brazilian institutions and #131 worldwide.

When scientific knowledge related to biodiesel is narrowed to include engines as well, the Brazilian contribution becomes significantly less important at the world level. The country ranked 17th worldwide in 2022, responsible for 1.6% of all publications, behind India (36.9%), China (7.1%), Malaysia (5.1%), and several other countries. Actually, scientific knowledge related to biodiesel in Brazil is systematically less focused on engines when compared to knowledge produced elsewhere (Figure 7).

4.2.2 Technological knowledge

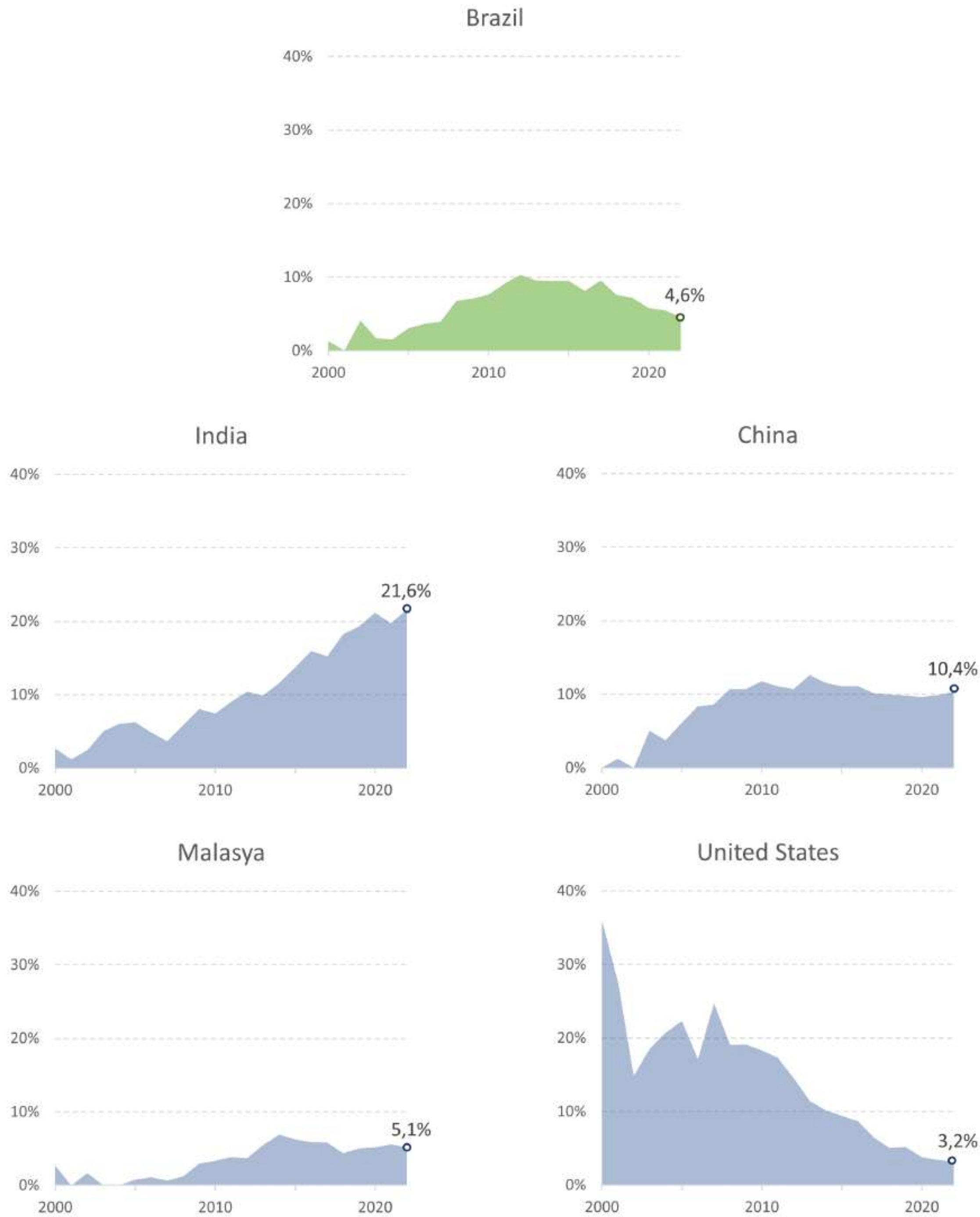
Technological knowledge was represented by granted patents. As in the case of scientific knowledge, the development of technological knowledge on biodiesel followed a decreasing trend after 2007, as notable in the data shown in Figure 8. International interest in securing technology for the Brazilian biodiesel market has also decreased substantially over the years (Figure 9). If, in the 2007-2012 period, 41% to 27% of patents granted by the Brazilian Patent Office (*Instituto Nacional da Propriedade Industrial*) (INPI) listed in their applicants at least one foreign institution, afterwards, the international share varied between 25% to zero.

Petrobras has by far the most prominent role in technological knowledge creation about biodiesel in Brazil since the company was granted almost twice the patents secured by the second-ranked institution, the Federal University of Paraná (Table 3). Seven of Petrobras's patents are joint ownerships with universities, six of those with the Federal University of Rio de Janeiro (UFRJ), located in the city of Rio de Janeiro, where Petrobras's R&D Center (CENPES) is also located. Figure 10 demonstrates that even Petrobras's interest in the biofuel has been on a decreasing trend.

Evonik is the only international company ranked amongst the top ten creators of technological knowledge in Brazil. The German chemical company has an R&D laboratory in Americana (São Paulo, Brazil) (49) and is the main catalyst supplier for the Brazilian biodiesel market (50). The input – NaOMe, sodium methylate, is a chemical compound that, despite other applications, is used primarily as a catalyst for transesterification with methanol – is produced at a plant in Rosario (Argentina) (51).

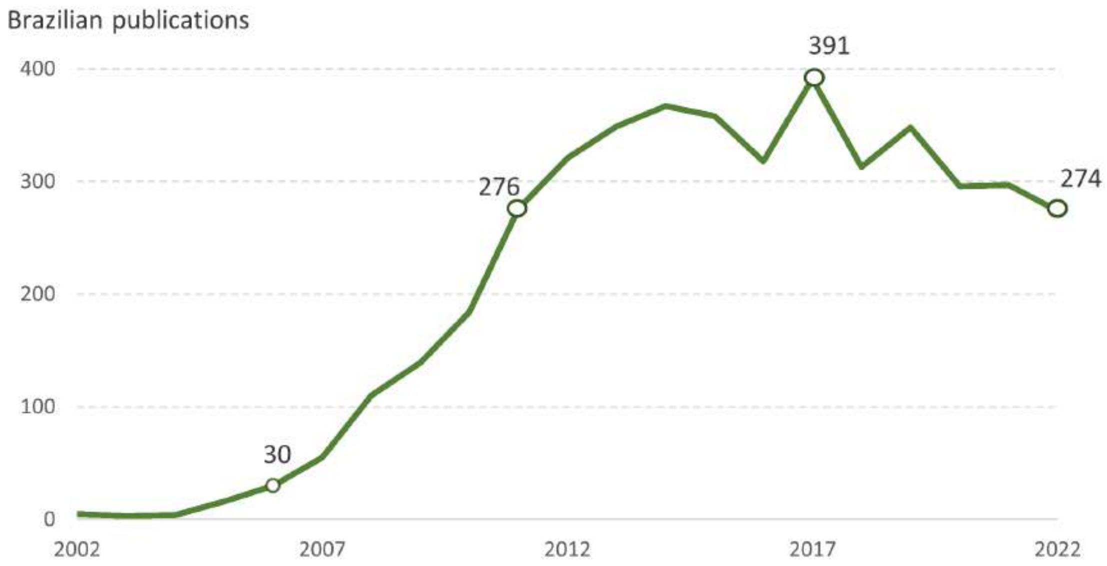
In addition to Petrobras, the only biodiesel producers that have patents are Cargill – one application in 2003 and another in 2007, both concerning corn oil –; Be8 (former BSBIOS) – whose two applications were submitted in 2022, one for biodiesel production and the other about its composition –; and Olfar – one patent about the production process whose application was filled in 2019. This is another relevant evidence of the lack of knowledge production by the Brazilian biodiesel private industry. None of the six patents on biodiesel granted to vehicle manufacturers specifically concern engines.

Figure 4 – Share per country of publications on biodiesel (2000-2022)



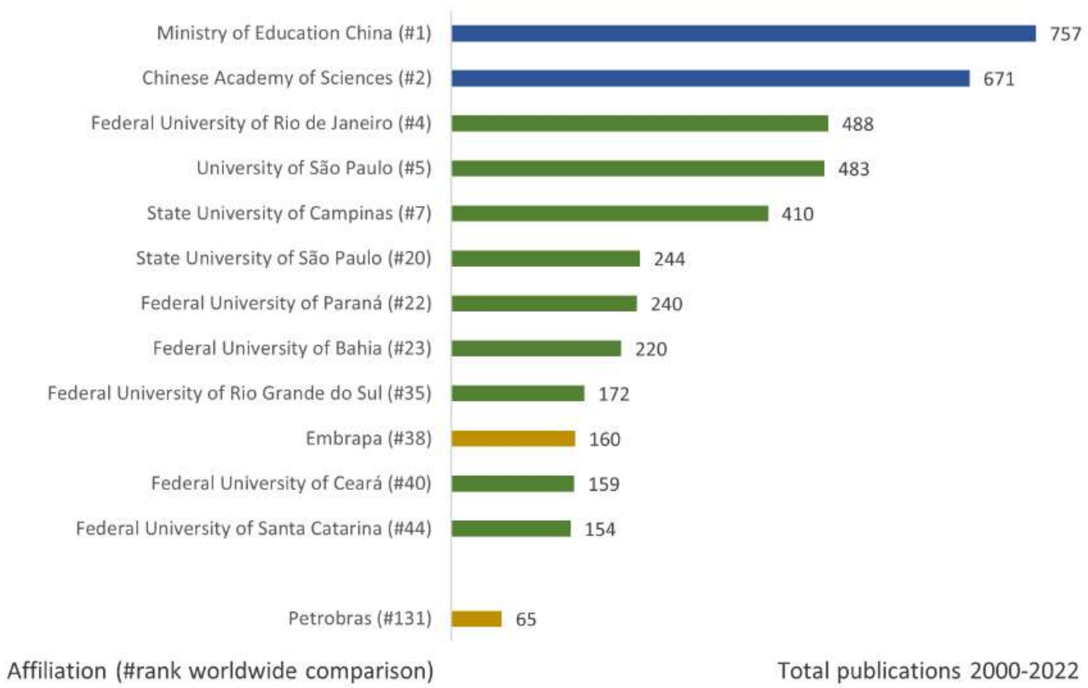
Source: created by the author using documents extracted from Scopus, including articles, conference papers, reviews, book chapters, notes, conference reviews, books, short surveys, editorials, letters, data papers, abstract reports, and business articles, with the word “biodiesel” in their title and/or abstract and/or keywords.

Figure 5 – Brazilian publications on biodiesel (2002-2022)



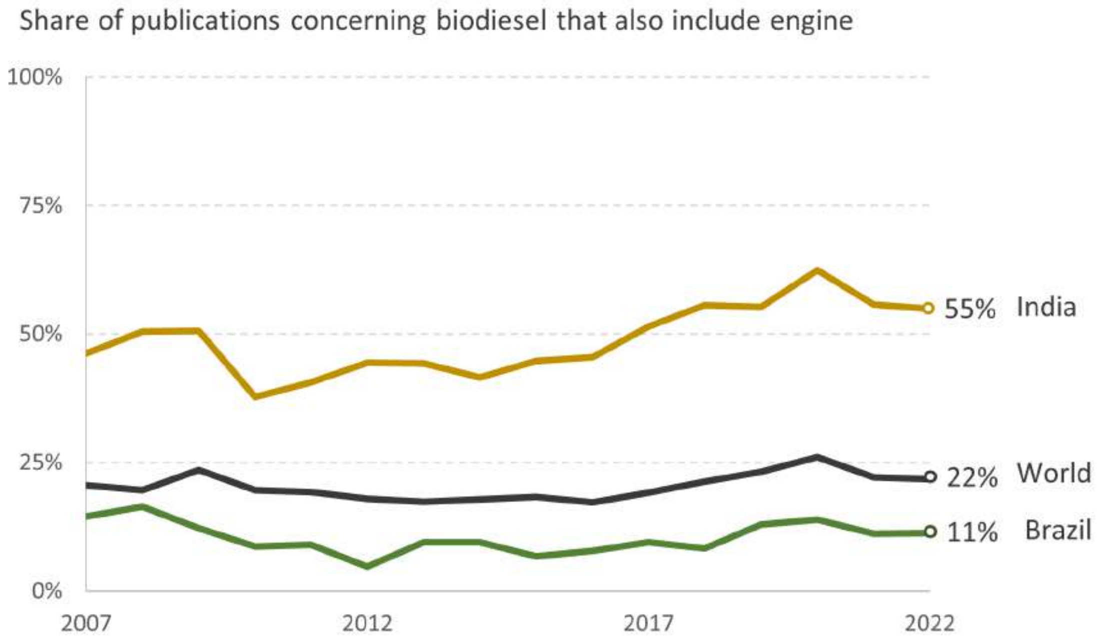
Source: created by the author using documents extracted from Scopus with the same criteria from Figure 4.

Figure 6 – Documents related to biodiesel by researcher affiliation including two Chinese institutions that lead the world rank, the top ten Brazilian organizations, and Petrobras (2000-2022)



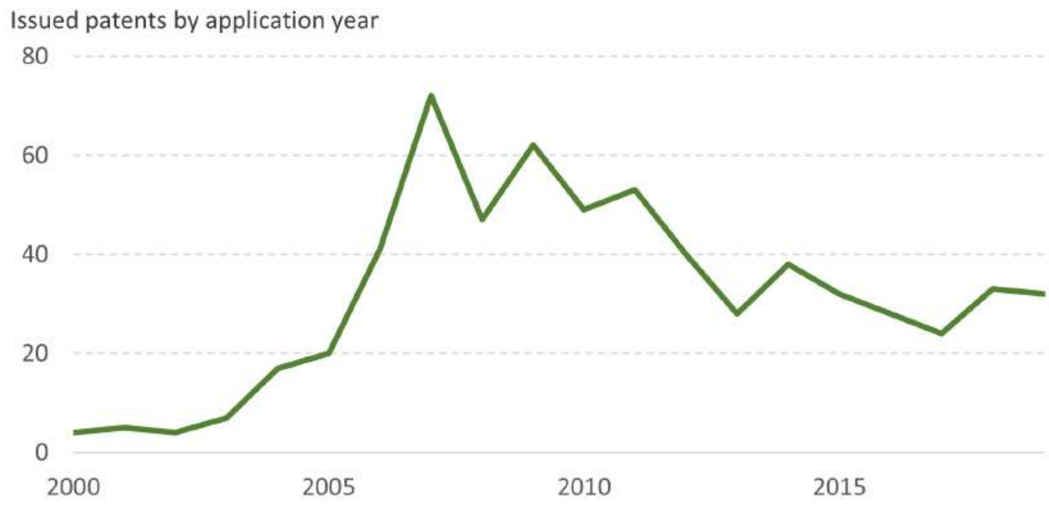
Source: created by the author using documents extracted from Scopus with the same criteria from Figure 4.
Note: Chinese organizations are displayed in grey, Brazilian universities in blue, and Brazilian companies in yellow.

Figure 7 – Share of total publications on biodiesel that also study engines, per country (2007-2022)



Source: created by the author using documents extracted from Scopus, with the word "biodiesel" and the word "engine" in their titles and/or abstracts and/or keywords.

Figure 8 – Issued patents by INPI per application year (2000-2019)

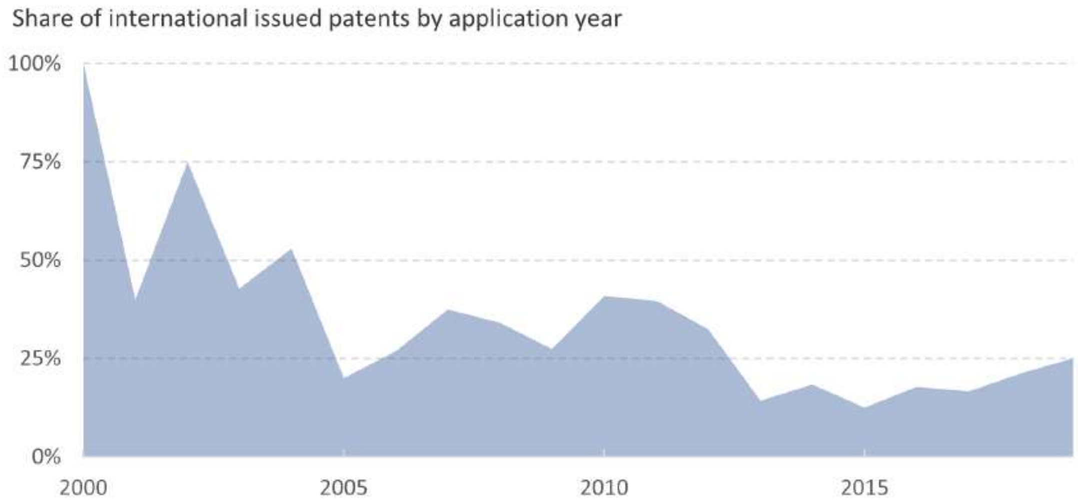


Source: created by the author using patents extracted from LATIPAD - Espacenet, with the word "biodiesel" in their title or abstract.
Note: the average time required for granting a patent on biodiesel was 2.6 years, with a minimum of zero and a maximum of 12 years.

4.2.3 Share of innovators

As shown in Table 4, most biodiesel producers surveyed by IBGE declare to have implemented product or process innovations in the evaluated periods; a fairly sta-

Figure 9 – Share of issued patents by INPI per application year (2000-2019) with at least one international applicant



Source: created by the author using patents extracted from LATIPAD - Espacenet, with the word “biodiesel” in their title or abstract.

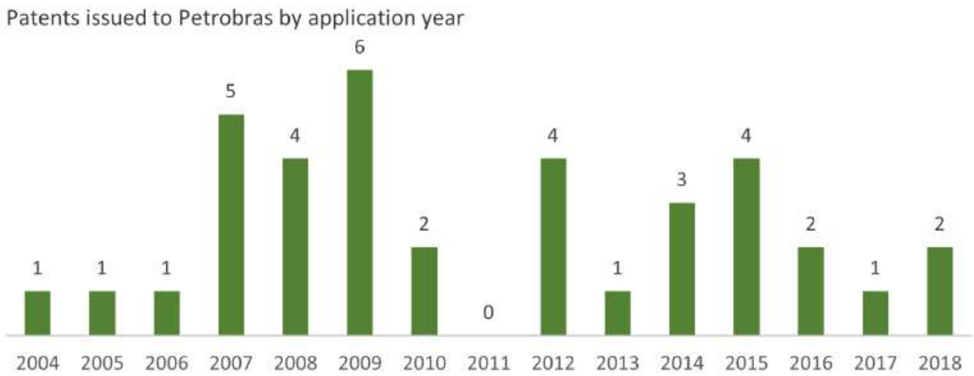
Table 3 – Patents issued by INPI, per applicant, related to biodiesel (2000-2022)

Ranking	Applicant	Country	Nº of Patents
1	Petrobras	BR	41
2	Federal University of Paraná (UFPR)	BR	22
3	State University of Campinas (UNICAMP)	BR	20
4	Federal University of Minas Gerais (UFMG)	BR	17
5	Federal University of Rio de Janeiro (UFRJ)	BR	14
6	State University of Londrina (UEL)	BR	13
7	Federal University of Bahia (UFBA)	BR	11
8	University of São Paulo (USP)	BR	9
9	Evonik Industries	DE	8
...			
Other	BSBIOS	BR	2
Biodiesel	Cargill	US	2
producers	OLFAR	BR	1
...			
Vehicles producers	Peugeot	BR	3
	Ford Motors	BR	2
	Fiat Chrisler	BR	1

Source: created by the author using patents extracted from LATIPAD - Espacenet, with the word “biodiesel” in their title or abstract.

ble share over time (2009-2017). This rate is considerably higher than the one for the Brazilian industry in general (36% in 2017), and the one for “producers of coke, petroleum products, and biofuels” (42% in 2017). The data suggest the existence of an innovative industry, in contradiction not only with the other learning indicators, but also with the R&D expenditures of biodiesel producers, detailed in Section 4.6.

Figure 10 – Patents granted to Petrobras by INPI, per application year (2000-2018)



Source: created by the author using patents extracted from LATIPAD - Espacenet, with the word "biodiesel" in their title or abstract.

Table 4 – Share of innovators among biodiesel producers (2009-2017)

PINTEC	Period	Producers surveyed	Producers who implemented product or process innovations	Share of innovators
2011	2009-2011	22	16	73%
2014	2012-2014	26	16	62%
2017	2015-2017	25	18	72%

Source: created by the author, based on data from PINTEC exclusively for biodiesel producers.

4.3 Knowledge diffusion

Knowledge diffusion was described by accounting for existing networks,[4] not only those exclusively dedicated to diffusion, but also those that connect companies and which would probably enable exchanges. Network activity was measured by the amount of events held by each. Additionally, linkages were also observed by computing joint ownership of patents and joint authorship of scientific documents. Finally, the relative importance of external information for companies was accessed using PINTEC data.

In 2005, even before the compulsory blend was implemented, the Brazilian government created the Brazilian Biodiesel Network (54).[5] Coordinated by the MCTI, the network program had two objectives: to o build a management system to articulate several actors involved in research, development, and production of biodiesel; and to identify and manage technological bottlenecks that might arise with the evolution of the PNPB.

R&D initiatives, already signaling an initial guidance of search, were split into five categories: agriculture, storage, quality control, co-products, and production (54). Seven

[4] In the launch of the PNPB, many other smaller networks, especially within states or regions, were built, as presented in Sebrae (52) and BiodieselBR.com (53). No record of recent activities by these networks was found.

[5] *Rede Brasileira de Tecnologia de Biodiesel*

events held by that network happened in 2006 (I), 2007 (II), 2009 (III), 2010 (IV), 2012 (V), 2016 (VI), and 2019 (VII). A website dedicated to that network or to its events could not be found. Additionally, except for the 2019 event, the event papers are not easily found online, jeopardizing circulation.

The biodiesel producers are well organized in three main associations: *União Brasileira do Biodiesel e Bioquerosene (Ubrabio)* (55), *Associação dos Produtores de Biocombustíveis do Brasil (Aprobio)* (56), *Associação Brasileira das Indústrias de Óleos Vegetais (ABIOVE)* (57), as displayed in Table 5.

Table 5 – Associations involving biodiesel producers

Association	Creation	Role	Associates	Companies
União Brasileira do Biodiesel e Bioquerosene (Ubrabio)	2007	Interaction between society and government	* Producers of biodiesel and biokerosene, and their raw materials; * Equipment suppliers; * Producers of vegetable oil, and bran; * Industries of chemical inputs, technologies, and services related to the sector.	Bianchini BioÓleo BioPar Fiagril Granol Grupo Cereal Oleoplan Olfar Palma plan (grupo OleoPlan) Potencial Biofuga Brejeiro
Associação dos Produtores de Biocombustíveis do Brasil (Aprobio)	2011	Corporate and institutional representation in working groups to: * improve the quality of biofuels; * formulate and implement public policies, regulatory frameworks and incentives for the sector.	National producers of biodiesel, and other biofuels	3tentos Barralcool BioÓleo Bocchi Be8 Caramuru Delta Lar Minerva Biodiesel
Associação Brasileira das Indústrias de Óleos Vegetais (ABIOVE)	1981	* Cooperation in the implementation of sectorial policies; * Promotion of sustainability programs; * Generation of statistics used in sectoral studies.	Producers of bran, vegetable oils, and biodiesel.	ADM Amaggi Binatural Bunge Cargill Cofco Internacional Fiagril JBS 3tentos Agrex do Brasil Btg pactual CHS CJ Selecta Dual Imcopa LDC Óleos Menu Sodrugestvo Brasil Viterra

Sources: created by the author using data from associations websites (57, 56, 55).
Note: Biodiesel producers are marked in grey.

Ubrabio organizes, with the support of Embrapa Agroenergia, from the MAPA, and of the Parliamentary Group for Biodiesel (58), an annual event called Biodiesel Week. Four editions happened in 2020, 2021, 2022, and 2023 (59), listing as participants entrepreneurs, public agents, journalists and researchers (55). Another important event organized by the industry was the *BiodieselBR* Conference that has occurred once a year since 2007 and assembles the agents from the sector: biodiesel producers and their suppliers, fuel distributors, government, and researchers (60).

Petrobras established close cooperation with the Federal University of Rio de Janeiro (UFRJ), which includes a Center for Biofuels, Petroleum, and its Derivatives, inaugurated in 2012 and built with investments from both Petrobras and ANP (61). Of the seven patents granted to Petrobras with joint ownership, six belong to UFRJ. Out of 98 papers on biodiesel published by researchers affiliated with Petrobras between 2000 and 2022, 45 were co-authored with UFRJ researchers.

Several biodiesel producers that implemented product or process innovations declare that these innovations were achieved with cooperation (Table 6). However, this result is not compatible with the relative importance given to their sources of information, shown in Table 7. Generally, biodiesel producers find their internal information sources to have a higher importance than those external. Out of the external sources, the only ranked to be more important is “suppliers”.

Table 6 – Share of innovators that had cooperation (2009-2017)

PINTEC	Innovators	With cooperation	Share
2011	16	7	44%
2014	16	10	63%
2017	18	10	56%

Source: created by the author, based on data from PINTEC exclusively for biodiesel producers.

Biodiesel producers consider both universities and research centers to be irrelevant information sources, suggesting the ineffectiveness of university-company interaction. Furthermore, “conferences, meetings, technical papers”, and “fairs and exhibitions” are also deemed irrelevant by many surveyed producers, which indicates that the many attempts to build active knowledge flows through networks cannot be considered successful.

4.4 Guidance of the search

Guidance of the search was mapped by analyzing the main national policies aimed at influencing the direction of the research concerning biodiesel, especially its visions and potential targets. Four major programs and policies were probed in detail.

In 2002, the Ministry for Science, Technology and Innovation (*Ministério da Ciência, Tecnologia e Inovação*) (MCTI) founded PROBIODIESEL “to promote scientific and technological development of biodiesel from ethyl esters contained in pure and/or residual vegetable oils” (62).[6] To make that project viable, the Ministry created a national

[6] All expressions, names, sources, and passages herein originally in Portuguese have been freely translated by the author.

Table 7 – Biodiesel producers' sources of information and their relative importance (2009-2017)

Information Sources		Importance	Number of producers 2017	2014	2011
Internal	R&D Department	High	9	6	6
		Medium	1	1	1
		Low/Irrelevant	2	1	1
	Other internal departments	High	8	3	4
		Medium	8	7	6
		Low/Irrelevant	2	6	6
External	Outra empresa do grupo	High	3	2	2
		Medium	2	3	4
		Low/Irrelevant	4	3	4
	Suppliers	High	9	9	7
		Medium	6	5	6
		Low/Irrelevant	3	2	3
	Custumers	High	5	8	3
		Medium	6	5	7
		Low/Irrelevant	7	3	6
	Competition	High	2	6	2
		Medium	5	3	7
		Low/Irrelevant	11	7	7
	Consultants	High	4	6	2
		Medium	5	4	6
		Low/Irrelevant	9	6	8
	Universities	High	2	3	1
		Medium	2	-	3
		Low/Irrelevant	14	13	12
	Research centers	High	2	4	1
		Medium	3	3	3
		Low/Irrelevant	13	9	12
	Conferences, meetings, technical papers	High	3	7	2
		Medium	5	3	7
		Low/Irrelevant	10	6	7
	Fairs and exibitions	High	4	5	1
		Medium	4	3	7
		Low/Irrelevant	10	8	8
	Automated information networks	High	5	11	6
		Medium	8	3	3
		Low/Irrelevant	5	2	7
Total			18	16	16

Source: created by the author, based on data from PINTEC exclusively for biodiesel producers.

network of “more than 200 experts representing the federal, state, and municipal governments, academia and research entities, business associations, regulatory and funding agencies, cooperatives, and NGOs” (63). The objectives for technological development were distributed across four areas: technical specifications; quality and legal aspects; social / environmental viability and technical competitiveness; and economic viability.

Before implementing the Brazilian Network for Biodiesel in 2005, in 2003 and 2004 and in cooperation with 22 states, the MCTI mapped all installed competence in the country to serve as basis for the network structure (54). Then, that structure was split into five sub-networks (64): (i) raw materials; (ii) production; (iii) storage and stability; (iv) characterization and quality control; (v) co-products.

In 2018, the MCTI published a “Plan for Science, Technology, and Innovation on Renewable Energy and Biofuels”[7] that considered it strategic, in order to overcome technological challenges, to develop R&D actions focused on:

1. diversifying **raw materials** used for biodiesel production;
2. increasing the use of low quality and low-cost **raw materials**, with the adoption of other technologies to replace alkaline transesterification;
3. optimizing **production** technologies;
4. ensuring biodiesel **quality** while in **storage**;
5. simplifying the methodology for **quality** control;
6. increasing value for **co-products**; and
7. increasing the proportion of biodiesel in the blend to fossil diesel, safeguarding quality control.

In general, national policies aimed at developing technology concerning for biodiesel industry were consistent over time. From PROBIODIESEL in 2002, to the plan issued in 2018, basically the focus was on the same five areas: diversification of raw materials; production processes; storage and stability; characterization and quality control; and byproducts. In none of those policies, the improvement of diesel engines to work better with biodiesel were considered as a priority.

4.5 Market formation

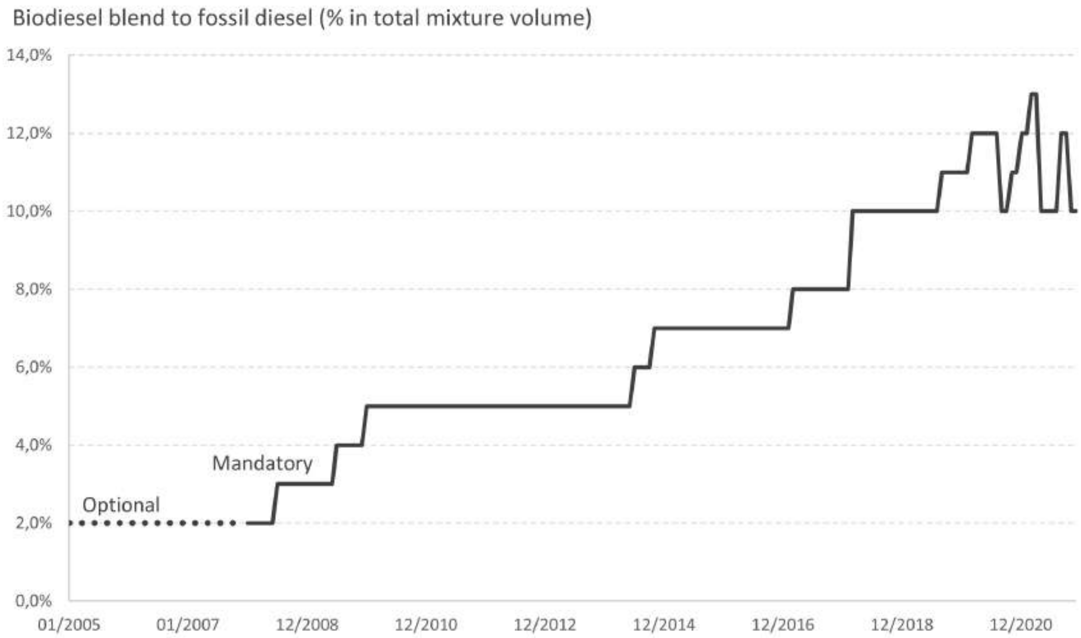
Market formation can be described from three perspectives. Firstly, based on the creation of a niche market and the sector’s evolution over time, comprising industry concentration, average plant capacity, and regional concentration. Secondly, it can be based on the establishment of a commercialization model, in force up to 2022, in addition to average prices of biodiesel compared with fossil diesel prices. Thirdly, tax benefits.

The niche market was created at the beginning of PNPB, by establishing a compulsory blend of biodiesel to all fossil diesels sold to final consumers in Brazil (2). The blend

[7] *Plano de Ciência, Tecnologia e Inovação para Energias Renováveis e Biocombustíveis*

level, originally set at 2% between 2008 and 2012, and 5% from 2013 onwards, at first grew more rapidly than initially planned (Figure 11).

Figure 11 – Biodiesel blend to fossil diesel (% in total mixture volume) (2005-2021)



Source: created by the author, based on data from the *Oil, Natural Gas, and Biofuels Statistical Yearbook* by ANP (3).

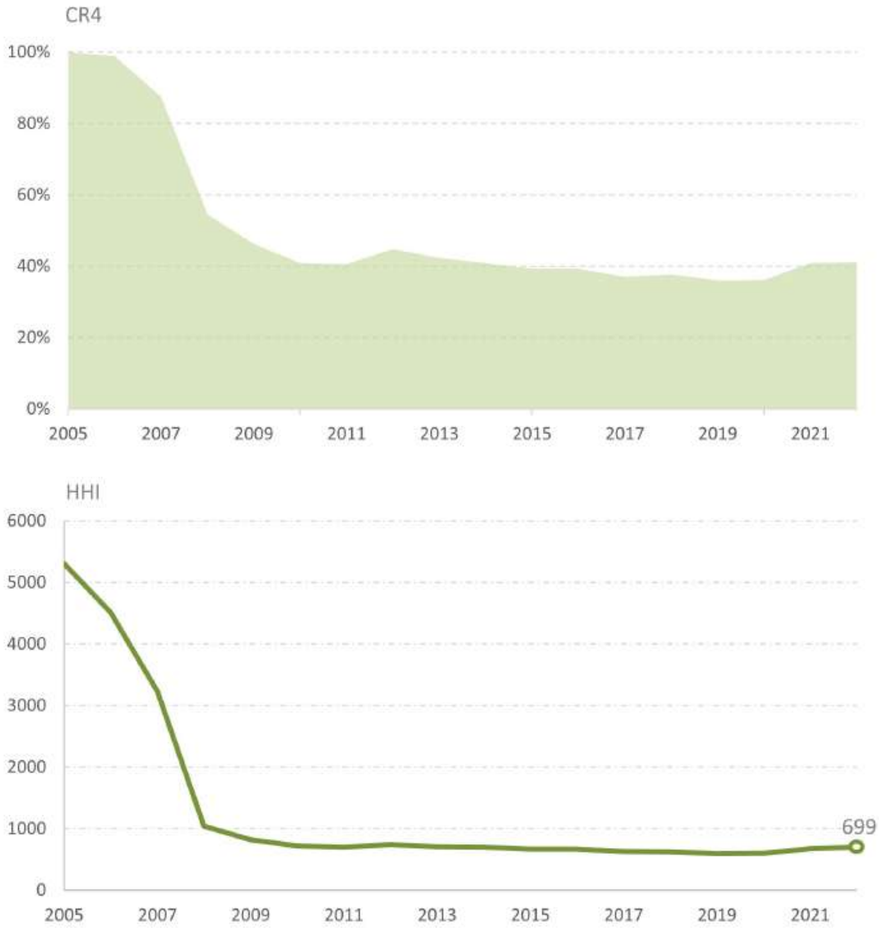
In this context, as discussed in Section 4.1, the market expanded at the outset with an increasing number of companies and therefore with decreasing concentration, which then underwent adjustments. In this adjustment period, market concentration reached the level where it still remained in 2022. CR4 is around 40%, and HHI, around 700, as seen in the data from Figure 12. Over time, the average production per plant (Figure 13) increased significantly, suggesting that small plants would have difficulties to survive in a mature market.

Regarding regional concentration, the plants responsible for 42% of the national production in 2022 are in the southern region, where cattle farming is quite relevant. Plants responsible for another 38% of production are in the Central-West region, the main soybean agribusiness production zone. As perceptible in Figure 14, production is very concentrated in these four main states, which in total produced 73% of Brazilian biodiesel in 2022. The location of the plants clearly correlates with locations where raw materials are manufactured.

According to the commercialization model formulated by PNPB (65) and in force up to early 2022 (66), biodiesel supplied by producers to the national market could only be sold in public auctions held by ANP to buyers who produced or imported fossil diesel in proportion to their market share. Importing biodiesel for the mandatory blend was prohibited in practice.[8] In this arrangement, Petrobras was granted a prominent role as the

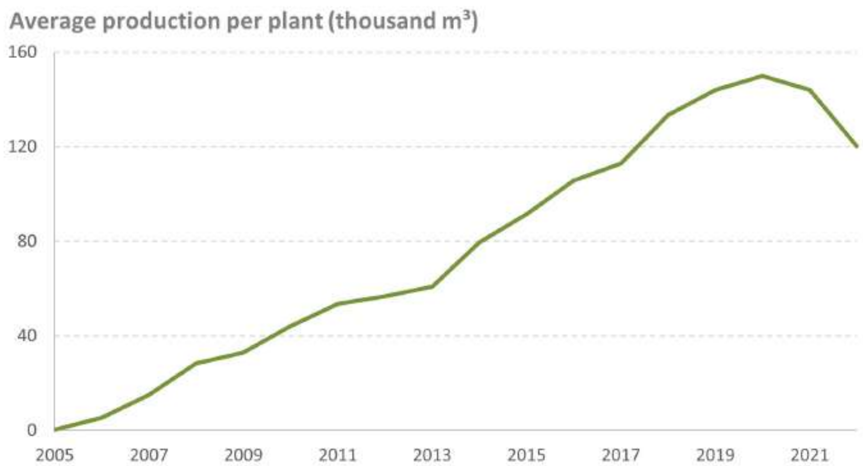
[8] International sellers were not allowed in the public auctions at first and, after auctions were ended,

Figure 12 – Biodiesel market concentration (2005-2022)



Source: created by the author, based on production data from ANP.

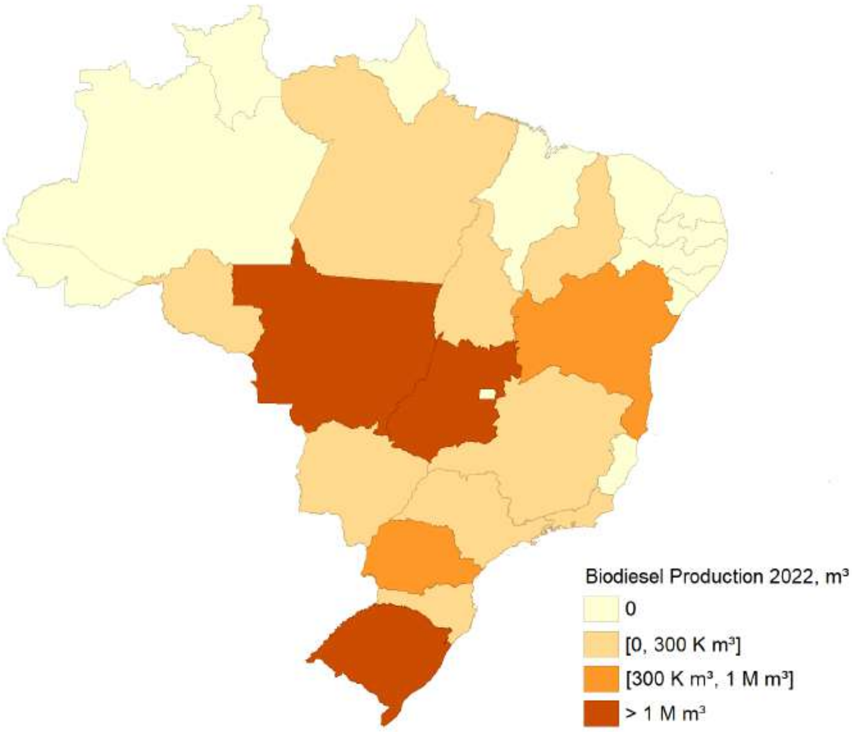
Figure 13 – Average production per plant in operation (2005-2022)



Source: created by the author, based on production data from ANP.

imported biodiesel was not considered to compose the mandatory blend.

Figure 14 – Biodiesel production per state (2022)



Source: created by the author, based on data from the *Oil, Natural Gas, and Biofuels Statistical Yearbook* by ANP (3).

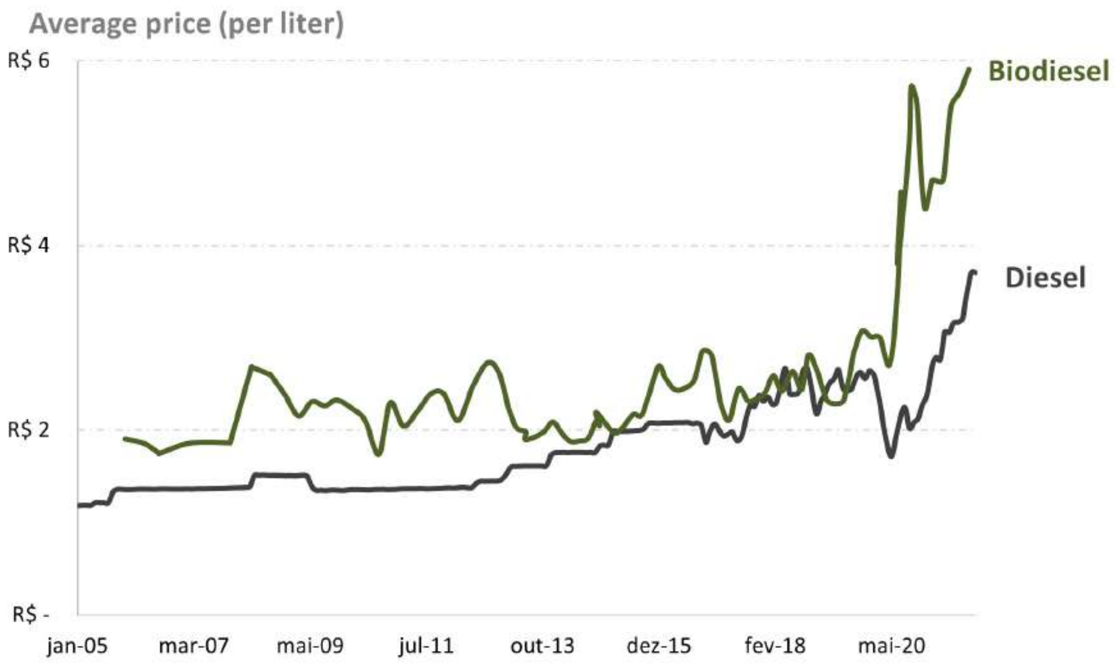
sole buyer in auctions, as its share in the national diesel market was over 99% (67, Item 3.1).[9]

Average prices of biodiesel sold in auctions is shown in Figure 15 with the fossil diesel average prices. Three different phases are distinguishable (8). In the first stage (January/2005 - October/2016), biodiesel prices were consistently higher than diesel ones. In this period, Petrobras did not set a pricing policy of aligning internal diesel prices with international ones (8). Then, in the second stage (October/2016 - March/2020), biodiesel became competitive with diesel. In October/2016, Petrobras announced the alignment of diesel prices to import parity prices (IPPs) (8). Despite the persistence of these pricing policies, in the third phase (March/2020 - December/2021), biodiesel prices increased considerably, mainly due to an increase in international prices of soybean that added to the devaluing of Brazilian real relative to the dollar, rendering the export of that commodity more lucrative, therefore reducing its internal availability (68).

Regarding tax benefits, the law states that the total tax rates and federal contributions for biodiesel could not be higher than those for fossil diesel (2). Furthermore, special incentives -– still in force (69) -– were granted to producers whose raw materials were palm and castor oil grown in the North and Northeast regions and semi-dry areas, and/or acquired from family agriculture business. These incentives are higher if both criteria are fulfilled (69). In fact, family agriculture was granted even further support. Out of the

[9] The auctions' operation is very well described in Dutra (8).

Figure 15 – Biodiesel and fossil diesel prices (2005-2021)



Source: created by the author, based on data from the *Oil, Natural Gas, and Biofuels Statistical Yearbook* by ANP (3).

biodiesel volume commercialized in public auctions, 80% had to be from raw materials produced by family farmers who participated in the PRONAF – National Program to Strengthen Family Agriculture (65).[10]

4.6 Resource mobilization

Resource mobilization can be described from four perspectives. Firstly, by evaluating the direct investment allocated to the creation of Embrapa Agroenergia. Secondly, by evaluating funding – both for innovative and non-innovative initiatives concerning biodiesel – allocated by the National Bank for Economic and Social Development (*Banco Nacional de Desenvolvimento Econômico e Social*) (BNDES) over the years. BNDES is the most important funding agency for long-term projects in Brazil and the key source of long-term committed finance in the Brazilian economy (70, p. 43). Thirdly, by analyzing the scientific publications on biodiesel that mentioned, as sponsors, the most relevant funding agencies for graduate programs and students in Brazil. Fourthly, by accessing the R&D expenditures of biodiesel producers.

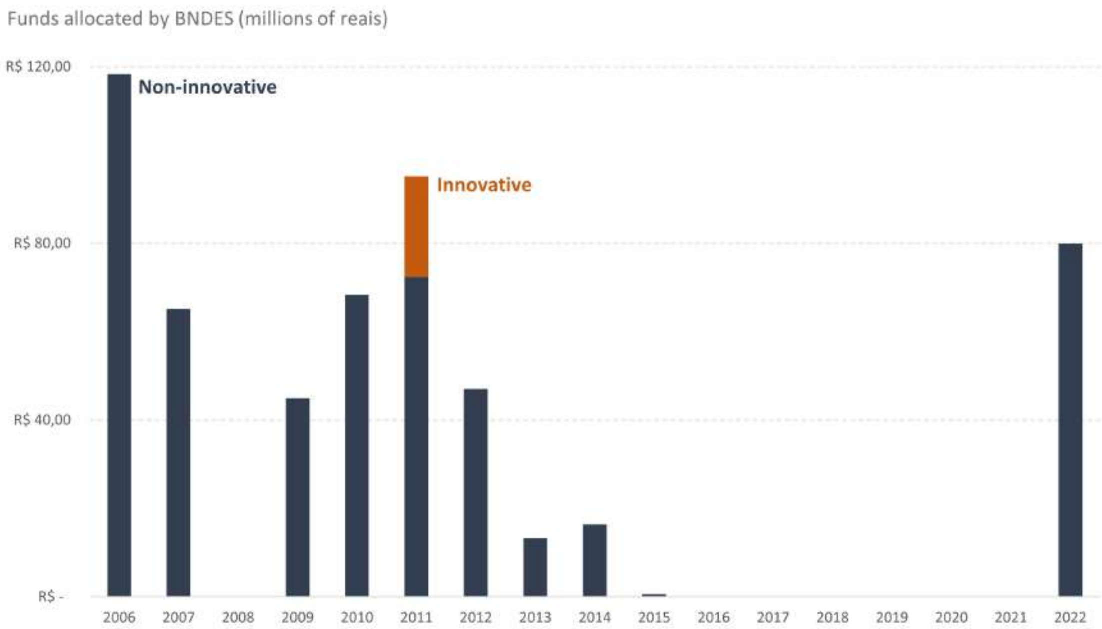
Embrapa Agroenergia was created alongside the establishment of PNPB, with the aim of ensuring an increase in the participation of renewable sources in the National Energy Balance. (71). Between 2008 and 2010, the government invested R$ 500 million in physical improvements, operating expenses, and personnel throughout the organization (72). Embrapa Agroenergia has a research center located in Brasília (Federal District)

[10] *Programa Nacional de Fortalecimento da Agricultura Familiar*

including: five laboratories; pilot plant area; greenhouses that support experiments with plant crops; two experimental areas, where 88 people are working (73).

Before the implementation of the compulsory blend in 2008, BNDES built a funding program comprising all stages of biodiesel production, from raw materials to the final product (74, p. 55). Indeed, in 2006, BNDES destined almost R$ 120 million[11] to projects related to biodiesel. Even with a decrease in support over the years (Figure 16), several biodiesel producers benefited from it and, in one specific case, a university developed an innovative project, as shown in Table 8.

Figure 16 – Funds allocated by BNDES to biodiesel-related projects (2006-2022)



Source: created by the author, based on data from BNDES.
Note: financing operations were filtered by sector "production of biofuels, except alcohol".

In the topic of scientific research funding, specifically, the two main Brazilian funding agencies for graduate programs and students – the National Council for Scientific and Technological Development[12] (CNPq) and the Coordination for the Improvement of Higher Education Personnel[13] (CAPES) – are, respectively, in the second and the third positions in the sponsors rank of published documents on biodiesel (Figure 17). Together, both agencies are acknowledged in 2,949 documents, almost 50% more than those that mention the top sponsor, the National Natural Science Foundation of China. FAPESP (São Paulo Research Foundation)[14] is also an important sponsor, fifth in the world ranking. Based on the evolution in published documents shown in Figure 18, those three institutions offered continued support to research on biodiesel over the years.

Data for biodiesel producers declared innovation expenditures is shown in Table 9. On average, the share of liquid sales allocated to innovation is very low compared to

[11] Approximately 53 million dollars in 2006 values.
[12] *Conselho Nacional de Desenvolvimento Científico e Tecnológico*
[13] *Coordenação de Aperfeiçoamento de Pessoal de Nível Superior*
[14] *Fundação de Amparo à Pesquisa do Estado de São Paulo*.

Table 8 – Funding granted by BNDES to biodiesel-related projects (2006-2022)

Company	Funding (millions of reais)	Innovative	Type
Granol	126,9		R
São Martinho	80,0		R
Potencial	52,0		R
Caramuru	42,8		R
BSBIOS	42,5		R
Tauá Biodiesel	39,6		R
Fiagrill	29,7		R
ADM	19,8		R
Senergen Energia Renovável	19,6 *	yes	R
COOPERBIO	17,2		R
Fuga Couros	16,9		R
OleoPlan	11,6		R
Camera Agroindustrial	10,0		R
Olfar	8,6		R
Delta	7,4		R
....			
FAI UFSCAR	3,2 *	yes	NR

Source: created by the author, based on data from BNDES.
Notes: R for reimbursable, and NR, for non-reimbursable.
* The funds for both innovative projects were granted in 2011.
Financing operations were filtered by sector "production of biofuels, except alcohol".

both the Brazilian industry in general (2.5% in 2017) and "producers of coke, petroleum products, and biofuels" (1.6% in 2017). Thus, despite the fact that most producers declare to have implemented innovations (Table 4), on average they invest very little in innovation, which is consistent with their very low knowledge production.

Table 9 – Biodiesel producers innovation expenditure (2009-2017)

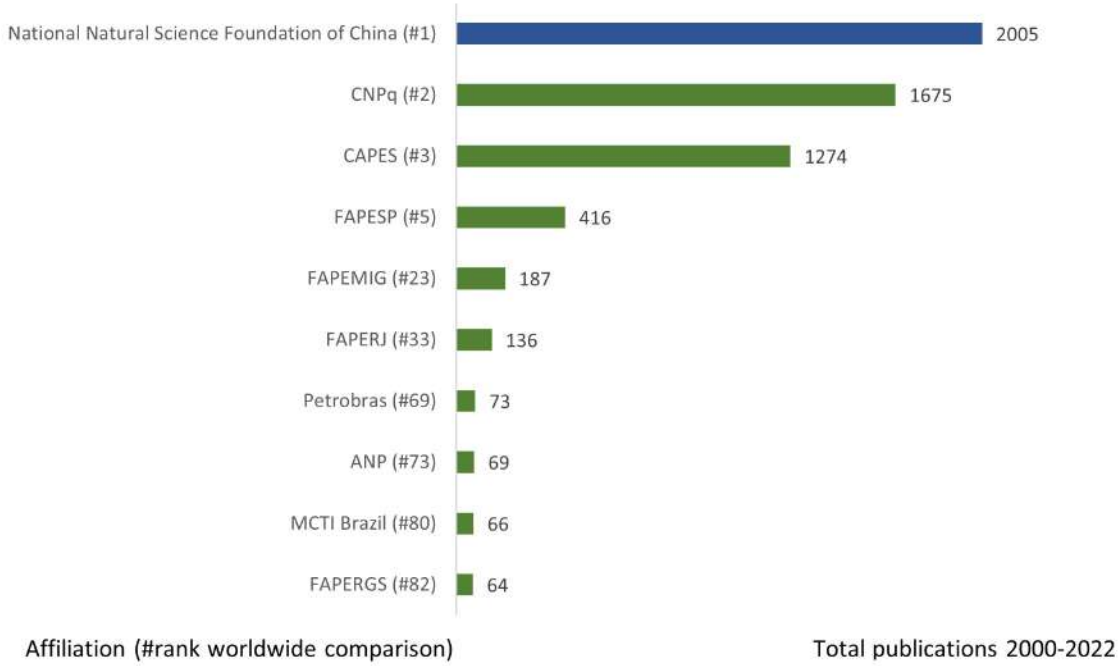
PINTEC	Liquid sales (million R$)	Total investments in innovation (million R$)	Share Innovation/ Sales	Internal investments in innovation (million R$)	Share Internal/Total
2011	77,034	89	0.1%	16	19%
2014	93,148	551	0.6%	27	5%
2017	133,675	281	0.2%	120	43%

Source: created by the author, based on data from PINTEC exclusively for biodiesel producers.

4.7 Support from advocacy coalitions

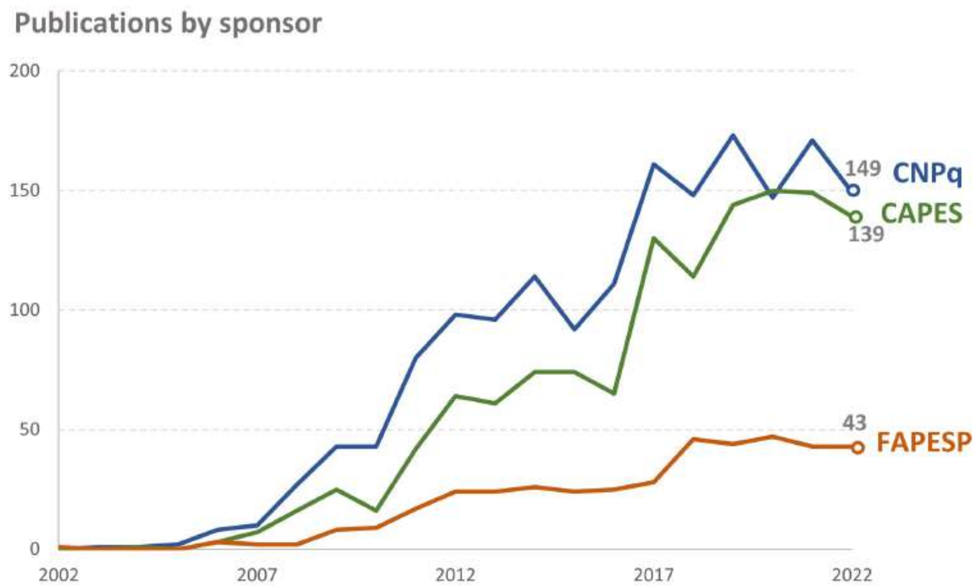
Support from advocacy coalitions was described by assessing legislative backing for the biodiesel industry. In addition to having their institutional interests represented by

Figure 17 – Documents related to biodiesel by declared sponsor including Chinese institution that leads the world rank and the top nine Brazilian institutions (2000-2022)



Source: created by the author using documents extracted from Scopus with the same criteria from Figure 4.
Note: the Chinese organization is displayed in blue, and Brazilian institutions, in green.

Figure 18 – Documents related to biodiesel with the top 3 Brazilian funding institutions as declared sponsors (2002-2022)



Source: created by the author using documents extracted from Scopus with the same criteria from Figure 4.

three associations, biodiesel producers rely on the Parliamentary Group for Biodiesel in Congress. Created in 2011 to facilitate dialogue between the sector and the federal government, it has been renewed thrice and makes up a significant share of the representatives (75), as shown in Table 10. Congressmen and congresswomen from the whole political spectrum compose this institutional board, ranging from the far left to the far right (76). All Brazilian 27 states have active members, São Paulo, Rio Grande do Sul, and Minas Gerais being the states sending most congresspeople.

Table 10 – National Congress representatives in the Parliamentary Group for Biodiesel

Legislature	Representatives (out of 513)	Senators (out of 81)	Total
2011-2015	231	8	239
2015-2019	234	0	234
2019-2023	203	3	206
2023-2027	204	16	220

Source: created by the author using data from BiodieselBR.com (75).

5 Conclusion

The expansion of Brazil's biodiesel industry has been both significant and rapid. Over the course of fifteen years, the industry has achieved a high-quality production output of 7 million cubic meters, accounting for 12.6% of the world's total production (4). The fuel's specifications adhere strictly to international standards.

The implementation of biodiesel industry in Brazil was predominantly government-led, beginning with the establishment of the National Program of Production and Use of Biodiesel (*Programa Nacional de Produção e Uso do Biodiesel*) (PNPB). First, a niche market was secured from the outset through the mandatory blend of biodiesel to diesel, a policy sustained over time through incremental increases in biodiesel share. Second, a commercialization model was instituted through public auctions, which remained in effect until 2022. Third, biodiesel has consistently enjoyed tax benefits compared to diesel. Fourth, public funding for the development of scientific and technological knowledge continued uninterrupted, facilitated by the expansion of Embrapa Agroenergia and sustained financing from Brazilian funding agencies. CNPq and Capes respectively ranked as the world's second and third largest supporters of biodiesel research. Fifth, the technological goals outlined by the PNPB remained consistent over time, providing stable guidance of the search. Sixth, the government established the Brazilian Biodiesel Network and organized continuous events from 2006 to 2019. Lastly, a well-established Parliamentary Group for Biodiesel, comprising approximately 40% of Congress representatives spanning from the far left to the far right, advocated for the industry's interests in the National Congress over time.

The biodiesel market in Brazil benefited from existing capacities following the remarkable success of the soybean agribusiness. Approximately 85% of Brazilian biodiesel is derived from soybean oil, an abundant feedstock with sufficient capacity to meet demand at reasonable costs, despite competition from soybean grain exports. Following an initial adjustment period, the market has maintained stable concentration levels over the past decade, accompanied by an increase in average production per plant. The industry appears to have reached a more mature stage, potentially posing barriers to entry for new companies. Among the top ten biodiesel producers with the largest production shares in 2022, five companies originally operated in the soybean agribusiness sector.

Despite systemic government initiatives, both the development of scientific and technological knowledge has experienced a decline in recent years. There is decreasing scientific interest in biodiesel in Brazil when compared to countries like India, China, and Malaysia. Long-term interest in ethanol played a pivotal role in establishing ethanol as a viable alternative to gasoline (13).

The findings also reveal minimal efforts by biodiesel producers to generate knowledge. Despite a high proportion claiming to have implemented product or process innovations, few patents were filed by producers other than Petrobras, and biodiesel producers allocate very little resources to innovation, especially when compared to Brazil's industry in general. In contrast, within the ethanol innovation system, the active involvement of diverse agents, including private companies such as suppliers, startups, distilleries, and mills, was crucial for success (13).

Despite the existence of long-standing knowledge diffusion networks that have organized numerous events, there is limited documentation available online, suggesting that information may not be easily accessible to researchers. Moreover, most biodiesel producers consider conferences, meetings, technical papers, fairs, and exhibitions as irrelevant sources of information. In the ethanol innovation system, the effective functioning of research networks also played a significant role in its success (13).

Overall, there has been limited interest in research exploring the association between biodiesel and engines. Engines have not been included in any of the government's technological goals. None of the six patents granted to vehicle manufacturers between 2000 and 2022 specifically addresses engines. In 2022, only 11% of Brazilian publications on biodiesel also included engines, compared to 22% worldwide and 55% in India. Despite the possibility of using biodiesel without any engine modification, there remains significant potential for improvement. Enhancements in fuel use in engines are fundamental for more widespread adoption of the technology. In the case of ethanol development in Brazil, FFVs played an essential role in making ethanol viable.

Cooperation between universities and industry was found to be relevant only for Petrobras and Embrapa, who cooperated in research centers, joint papers and shared patents. However, most biodiesel producers declare to consider universities as irrelevant sources of information. This disparity may be attributed to the geographical distance between productive universities and the majority of biodiesel plants. While the most productive universities conducting research on biodiesel are situated in the states of Rio de Janeiro, São Paulo, and Paraná, most biodiesel producers are located in Mato Grosso, Goiás, and Rio Grande do Sul. In contrast, during the development of the innovation system around ethanol, most of active agents -— including sugarcane refineries, startups, suppliers of capital goods, universities, public and private research centers, and governmental bodies -— were concentrated in São Paulo state (13). As it is well documented in the literature, geographical proximity may facilitate collaboration and knowledge exchange (77).

Finally, it is important to address two key aspects of the technological development goal aimed at diversifying feedstock for biodiesel production. On the one hand, reducing reliance on a single input, such as soybean oil, is crucial for the industry, especially considering the competition it faces from direct soybean grain exports. On the other hand, ensuring feedstock viability at an industrial scale demands a sufficient volume of biomass. Achieving this requires the development of scalable processing technologies tailored to each biomass type, as different biomasses necessitate distinct processing methods. However, achieving the diversification goal necessitates sustained long-term research efforts, as demonstrated by the case of soybean, whose remarkable productivity is attributed to technological advancements made in the latter half of the 20^{th} century (15). Nevertheless, as these new feedstocks mature enough for industrial-scale supply, they will encounter a well-structured industry that has already reached a more mature stage.

REFERENCES

1 HEKKERT, M. *et al.* Functions of innovation systems: A new approach for analysing technological change. en. **Technological Forecasting and Social Change**, v. 74, n. 4, p. 413–432, May 2007. ISSN 00401625. DOI: 10.1016/j.techfore.2006.03.002.

2 BRASIL. **Lei nº 11.116**. May 2005. Available from: http://www.planalto.gov.br/ccivil_03/_ato2004-2006/2005/Lei/L11116.htm. Visited on: 15 Oct. 2023.

3 ANP. **Oil, Natural Gas and Biofuels Statistical Yearbook 2023**. en. 2023. Available from: https://www.gov.br/anp/pt-br/centrais-de-conteudo/publicacoes/anuario-estatistico/yearbook-2023. Visited on: 15 Oct. 2023.

4 BP. **Statistical Review of World Energy**. 2021. Available from: https://www.bp.com/en/global/corporate/energy-economics/statistical-review-of-world-energy.html. Visited on: 9 Nov. 2023.

5 NOGUEIRA, L. A. *et al.* Biodiesel program in Brazil: learning curve over ten years (2005–2015). en. **Biofuels, Bioproducts and Biorefining**, v. 10, n. 6, p. 728–737, Nov. 2016. ISSN 1932-104X, 1932-1031. DOI: 10.1002/bbb.1718.

6 CNPE. **Relatório Final sobre a Inserção de Biocombustíveis no Ciclo Diesel**. 2021. Available from: https://www.gov.br/mme/pt-br/assuntos/noticias/cnpe-adota-periodo-de-transicao-para-alterar-o-percentual-da-mistura-de-biodiesel-no-oleo-diesel/RELATORIO_GT_CNPE_13_2020_VERSAO_FINAL_PUBLICACAO.pdf. Visited on: 26 Sept. 2023.

7 DOS SANTOS ALVES, C. E.; BELARMINO, L. C.; PADULA, A. D. Feedstock diversification for biodiesel production in Brazil: Using the Policy Analysis Matrix (PAM) to evaluate the impact of the PNPB and the economic competitiveness of alternative oilseeds. en. **Energy Policy**, v. 109, p. 297–309, Oct. 2017. ISSN 03014215. DOI: 10.1016/j.enpol.2017.07.009.

8 DUTRA, R. C. D. **Alcance dos objetivos do Programa Nacional de Produção e Uso do Biodiesel através dos leilões públicos e proposta de um modelo integrado de análise do impacto do biodiesel no bem-estar com incorporação de externalidades**. Nov. 2022. PhD thesis – Universidade Federal do Rio de Janeiro, Rio de Janeiro. Available from: http://www.ppe.ufrj.br/images/publica%C3%A7%C3%B5es/doutorado/Tese_Renato_Cabral_Dias_Dutra.pdf. Visited on: 13 Oct. 2023.

9 ANP. **Documentos e resultados dos leilões de biodiesel**. pt. Oct. 2021. Available from: https://www.gov.br/anp/pt-br/assuntos/distribuicao-e-revenda/leiloes-biodiesel/documentos-resultados-leiloes-biodiesel. Visited on: 17 Oct. 2023.

10 NIKAS, A. *et al.* A comparative study of biodiesel in Brazil and Argentina: An integrated systems of innovation perspective. en. **Renewable and Sustainable Energy Reviews**, v. 156, p. 112022, Mar. 2022. ISSN 13640321. DOI: 10.1016/j.rser.2021.112022.

11 BRASIL, M. Lula confirma apoio à antecipação da mistura obrigatória de biodiesel. pt. **epbr**, Sept. 2023. Available from: https://epbr.com.br/lula-confirma-apoio-a-antecipacao-da-mistura-obrigatoria-de-biodiesel/. Visited on: 17 Oct. 2023.

12 KNOTHE, G.; RAZON, L. F. Biodiesel fuels. en. **Progress in Energy and Combustion Science**, v. 58, p. 36–59, Jan. 2017. ISSN 03601285. DOI: 10.1016/j.pecs.2016.08.001.

13 FURTADO, A. T.; SCANDIFFIO, M. I. G.; CORTEZ, L. A. B. The Brazilian sugarcane innovation system. en. **Energy Policy**, v. 39, n. 1, p. 156–166, Jan. 2011. ISSN 03014215. DOI: 10.1016/j.enpol.2010.09.023. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0301421510007093. Visited on: 26 Jan. 2024.

14 DEDINI. **Plantas e Equipamentos para PRODUÇÃO DE BIODIESEL**. 2024. Available from: https://www.dedini.com.br/index.php/setores-de-mercado/bio-equipamentos-e-plantas/biodiesel. Visited on: 18 Apr. 2024.

15 KLEIN, H. S.; LUNA, F. V. **Alimentando o mundo: O surgimento da moderna economia agrícola no Brasil**. 1. ed. Rio de Janeiro: FGV Editora, 2020. ISBN 978-85-225-2171-5.

16 ANP. **Resolução ANP nº 920**. Apr. 2023. Available from: https://atosoficiais.com.br/anp/resolucao-n-920-2023-estabelece-a-especificacao-do-biodiesel-e-as-obrigacoes-quanto-ao-controle-da-qualidade-a-serem-atendidas-pelos-agentes-economicos-que-comercializem-o-produto-em-territorio-nacional?origin=instituicao. Visited on: 19 Apr. 2024.

17 ASTM. **ASTM Biodiesel Specifications**. Mar. 2023. Available from: https://afdc.energy.gov/fuels/biodiesel-specifications. Visited on: 19 Apr. 2024.

18 ÖZENER, O. *et al.* Effects of soybean biodiesel on a DI diesel engine performance, emission and combustion characteristics. en. **Fuel**, v. 115, p. 875–883, Jan. 2014. ISSN 00162361. DOI: 10.1016/j.fuel.2012.10.081. Available from: https://linkinghub.elsevier.com/retrieve/pii/S0016236112009544. Visited on: 19 Apr. 2024.

19 GOEL, V.; KUMAR, N.; SINGH, P. Impact of modified parameters on diesel engine characteristics using biodiesel: A review. en. **Renewable and Sustainable Energy Reviews**, v. 82, p. 2716–2729, Feb. 2018. ISSN 13640321. DOI: 10.1016/j.rser.2017.09.112.

20 FREEMAN, C. The 'National System of Innovation' in historical perspective. en. **Cambridge Journal of Economics**, p. 5–24, Feb. 1995. ISSN 1464-3545. DOI: 10.1093/oxfordjournals.cje.a035309.

21 FREEMAN, C. **Technology, Policy, and Economic Performance: Lessons from Japan**. Pinter Publishers, 1987. ISBN 978-0-86187-928-1. Available from: https://books.google.com.br/books?id=rA20AAAAIAAJ.

22 CARLSSON, B.; STANKIEWICZ, R. On the nature, function and composition of technological systems. en. **Journal of Evolutionary Economics**, v. 1, p. 93–118, 1991.

23 JOHNSON, A. **Functions in Innovation System Approaches**. en. Aalborg, Denmark, May 2001.

24 BERGEK, A. *et al.* Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. en. **Research Policy**, v. 37, n. 3, p. 407–429, Apr. 2008. ISSN 00487333. DOI: 10.1016/j.respol.2007.12.003.

25 BERGEK, A. Technological innovation systems: a review of recent findings and suggestions for future research. *In:* HANDBOOK of Sustainable Innovation. Edward Elgar Publishing, 2019. p. 200–218. ISBN 978-1-78811-257-4. DOI: 10.4337/9781788112574.00019.

26 ANDERSEN, A. D. A functions approach to innovation system building in the South: the pre-Proálcool evolution of the sugarcane and biofuel sector in Brazil. en. **Innovation and Development**, v. 5, n. 1, p. 1–21, Jan. 2015. ISSN 2157-930X, 2157-9318. DOI: 10.1080/2157930X.2014.996855.

27 DANTAS, E. The evolution of the knowledge accumulation function in the formation of the Brazilian biofuels innovation system. en. **International Journal of Technology and Globalisation**, v. 5, n. 3/4, p. 327, 2011. ISSN 1476-5667, 1741-8194. DOI: 10.1504/IJTG.2011.039770.

28 DE SOUSA, L. *et al.* Innovation Systems of Ethanol in Brazil and the United States: Making a New Fuel Competitive. *In:* GLOBAL Bioethanol. Elsevier, 2016. p. 93–121. ISBN 978-0-12-803141-4. DOI: 10.1016/B978-0-12-803141-4.00004-6.

29 DE OLIVEIRA, L. G. S.; NEGRO, S. O. Contextual structures and interaction dynamics in the Brazilian Biogas Innovation System. en. **Renewable and Sustainable Energy Reviews**, v. 107, p. 462–481, June 2019. ISSN 13640321. DOI: 10.1016/j.rser.2019.02.030.

30 FURTADO, A. T.; HEKKERT, M. P.; NEGRO, S. O. Of actors, functions, and fuels: Exploring a second generation ethanol transition from a technological innovation systems perspective in Brazil. en. **Energy Research & Social Science**, v. 70, p. 101706, Dec. 2020. ISSN 22146296. DOI: 10.1016/j.erss.2020.101706.

31 URIONA-MALDONADO, M. *et al.* The Diffusion of Solar Photovoltaics in Brazil: A Technological Innovation System Approach. *In:* PEREIRA, L. *et al.* (eds.). **Proceedings of IDEAS 2019: The Interdisciplinary Conference on Innovation, Design, Entrepreneurship, And Sustainable Systems**. Cham: Springer International Publishing, 2021. v. 198. (Smart Innovation, Systems and Technologies). p. 377–385. ISBN 978-3-030-55373-9 978-3-030-55374-6. DOI: 10.1007/978-3-030-55374-6.

32 NEGRO, S. O.; HEKKERT, M. P.; SMITS, R. E. Explaining the failure of the Dutch innovation system for biomass digestion—A functional analysis. en. **Energy Policy**, v. 35, n. 2, p. 925–938, Feb. 2007. ISSN 03014215. DOI: 10.1016/j.enpol.2006.01.027.

33 FURTADO, A. T. Indústria do Petróleo e Gás Natural: uma vocação desperdiçada. pt. **Cadernos do Desenvolvimento**, v. 14, n. 24, p. 155–175, 2019.

34 RODRIGUES, A. Policy, regulation, development and future of biodiesel industry in Brazil. en. **Cleaner Engineering and Technology**, v. 4, p. 100197, Oct. 2021. ISSN 26667908. DOI: 10.1016/j.clet.2021.100197.

35 BE8. **Empresa | História**. 2020. Available from: https://www.bsbios.com/pt/historico. Visited on: 6 Oct. 2023.

36 BE8. **Relatório de Sustentabilidade**. 2022. p. 132. Available from: https://www.bsbios.com/pt/publicacoes/Visualizar/relatorio-de-sustentabilidade-2022#book/. Visited on: 6 Oct. 2023.

37 OLFAR. **OLFAR | Produtos | Biodiesel**. 2023. Available from: https://www.olfar.ind.br/produtos-olfar/biodiesel/. Visited on: 13 Oct. 2023.

38 OLEOPLAN. **Oleoplan**. 2023. Available from: https://www.oleoplan.com.br/. Visited on: 13 Oct. 2023.

39 JBS. **JBS Biodiesel**. 2023. Available from: https://jbs.com.br/marca/jbs-biodiesel/. Visited on: 13 Oct. 2023.

40 ADM. **ADM | Products | Biodiesel**. 2023. Available from: https://www.adm.com/en-us/products-services/industrial-biosolutions/products/biodiesel/. Visited on: 13 Oct. 2023.

41 POTENCIAL. **Potencial | Petróleo | Sobre**. 2023. Available from: https://potencial.net.br/petroleo/sobre. Visited on: 14 Oct. 2023.

42 CARAMURU. **Caramuru | Biodiesel**. 2023. Available from: https://www.caramuru.com/?page_id=497. Visited on: 14 Oct. 2023.

43 BINATURAL. **Binatural | Biodiesel**. 2023. Available from: https://binatural.com.br/historia/. Visited on: 14 Oct. 2023.

44 GRANOL. **Granol**. 2023. Available from: http://www.granol.com.br/. Visited on: 14 Oct. 2023.

45 BIODIESELBR.COM. JBS vai incorporar a Biocamp. **BiodieselBR**, Apr. 2015. Available from: https://www.biodieselbr.com/noticias/usinas/info/jbs-incorporar-biocamp-290415. Visited on: 13 Oct. 2023.

46 BIODIESELBR.COM. ADM amplia unidade de processamento de soja em Santa Catarina. **BiodieselBR**, Apr. 2011. Available from: https://www.biodieselbr.com/noticias/em-foco/adm-processamento-soja-sc-041011vvvv.

47 BIODIESELBR.COM. Perfil da Indústria: Binatural. **BiodieselBR**, Mar. 2009. Available from: https://www.biodieselbr.com/revista/009/binatural-1. Visited on: 14 Oct. 2023.

48 BIODIESELBR.COM. Be8 aposta no hidrogênio em estratégia renovada de internacionalização. **BiodieselBR**, Oct. 2023. Available from: https://www.biodieselbr.com/noticias/usinas/info/be8-aposta-no-hidrogenio-em-estrategia-renovada-de-internacionalizacao-100523. Visited on: 10 Oct. 2023.

49 EVONIK. **América Central e do Sul, uma forte presença**. Sept. 2023. Available from: https://central-south-america.evonik.com/pt/company/regional/locations. Visited on: 16 Sept. 2023.

50 BIODIESELBR.COM. Evonik inicia construção de fábrica de metilato em Singapura. **BiodieselBR**, Aug. 2023. Available from: https://www.biodieselbr.com/noticias/usinas/insumo/evonik-inicia-construcao-de-fabrica-de-metilato-em-singapura-080523. Visited on: 16 Sept. 2023.

51 EVONIK. **Evonik opens a new plant in Argentina for catalysts used in biodiesel production**. Oct. 2013. Available from: https://corporate.evonik.com/en/investor-relations/evonik-opens-a-new-plant-in-argentina-for-catalysts-used-in-biodiesel-production-107001.html. Visited on: 16 Sept. 2023.

52 SEBRAE. **Biodiesel**. 2008. Available from: https://www.agencia.cnptia.embrapa.br/Repositorio/NT00035116_000gihb7tn102wx5ok05vadr1szzvy3n.pdf.

53 BIODIESELBR.COM. As Iniciativas Regionais e Estaduais em torno do Biodiesel. pt. **BiodieselBR**, July 2006. Available from: https://www.biodieselbr.com/destaques/2006/biodiesel-iniciativas-regionais.

54 MME. **A Rede Brasileira de Tecnologia de Biodiesel**. 2005. Available from: https://antigo.mme.gov.br/web/guest/secretarias/petroleo-gas-natural-e-biocombustiveis/acoes-e-programas/programas/biodiesel/rbtb. Visited on: 18 Sept. 2023.

55 UBRABIO. **Biodiesel Week**. Sept. 2023. Available from: https://ubrabio.com.br/biodieselweek/.

56 APROBIO. **Associação dos Produtores de Biocombustíveis do Brasil (Aprobio)**. Sept. 2023. Available from: https://aprobio.com.br/associadas. Visited on: 18 Sept. 2023.

57 ABIOVE. **Associação Brasileira das Indústrias de Óleos Vegetais (Abiove)**. Sept. 2023. Available from: https://abiove.org.br/. Visited on: 18 Sept. 2023.

58 BIODIESELBR.COM. Biodiesel Week chega a sua 4ª edição. **BiodieselBR**, Sept. 2023. Available from: https://www.biodieselbr.com/noticias/usinas/info/biodiesel-week-chega-a-sua-4-edicao-090823. Visited on: 18 Sept. 2023.

59 UBRABIO. **União Brasileira do Biodiesel e Bioquerosene (Ubrabio)**. Sept. 2023. Available from: https://ubrabio.com.br/sobre-nos/. Visited on: 18 Sept. 2023.

60 BIODIESELBR. **BiodieselBR Conference 2023**. 2023. Available from: https://conferencia.biodieselbr.com/2023/. Visited on: 18 Sept. 2023.

61 UFRJ. Escola de Química da UFRJ lança o Núcleo de Biocombustíveis, de Petróleo e de seus Derivados. **Conexão UFRJ**, June 2012. Available from: https://conexao.ufrj.br/2012/07/escola-de-quimica-da-ufrj-lanca-o-nucleo-de-biocombustiveis-de-petroleo-e-de-seus-derivados/. Visited on: 18 Sept. 2023.

62 MCTI. **Portaria MCT nº 702**. Oct. 2002. Available from: https://www.camara.leg.br/proposicoesWeb/prop_mostrarintegra;jsessionid=8362AE01F515A95B019F0C252F60C72C.proposicoesWebExterno2?codteor=122459&filename=LegislacaoCitada+-PL+526/2003. Visited on: 26 Sept. 2023.

63 MCTI. **PROBIODIESEL | Programa Brasileiro de Biodiesel**. Oct. 2002. Available from: https://www.camara.leg.br/internet/comissao/index/perm/capr/CAPR_BIOMCT.pdf. Visited on: 14 Oct. 2023.

64 EMPRABA. VII Congresso de Biodiesel é considerado sucesso por organizadores. **Empraba**, Nov. 2019. Available from: https://www.embrapa.br/busca-de-noticias/-/noticia/48463976/vii-congresso-de-biodiesel-e-considerado-sucesso-por-organizadores. Visited on: 18 Sept. 2023.

65 CNPE. **Resolução nº 5**. Mar. 2007. Available from: https://antigo.mme.gov.br/documents/36074/266757/Resolucao05.pdf. Visited on: 15 Oct. 2023.

66 CNPE. **Resolução nº 53**. Dec. 2020. Available from: https://www.in.gov.br/en/web/dou/-/despacho-do-presidente-da-republica-296859038. Visited on: 15 Oct. 2023.

67 ANP. **Edital de Leilão Público nº 003/21**. 2021. Available from: https://www.gov.br/anp/pt-br/assuntos/distribuicao-e-revenda/leiloes-biodiesel/180/180-edital.pdf. Visited on: 15 Oct. 2023.

68 BIOCOMBUSTÍVEL, P. **Relatório de Sustentabilidade 2020**. 2020. Available from: https://petrobras.com.br/lumis/portal/file/fileDownload.jsp?fileId=8AE99E8B7DC4C227017%20DC538BDB5735C. Visited on: 12 May 2022.

69 BRASIL. **Decreto nº 10.527**. Oct. 2020. Available from: http://www.planalto.gov.br/ccivil_03/_Ato2019-2022/2020/Decreto/D10527.htm#art9.

70 MAZZUCATO, M.; PENNA, C. **The Brazilian Innovation System: A Mission-Oriented Policy Proposal**. en. Brasília, Mar. 2016. Available from: https://www.cgee.org.br/temas-estrategicos.

71 EMBRAPA. **Embrapa Agroenergia | História**. 2020. Available from: https://www.embrapa.br/agroenergia/historia. Visited on: 23 Apr. 2024.

72 BIODIESELBR.COM. Após superar falta de estrutura e investimento, Embrapa Agroenergia comemora seis anos, May 2012. Available from: https://www.biodieselbr.com/noticias/pesquisa/embrapa-comemora-seis-anos-240512. Visited on: 23 Apr. 2024.

73 EMBRAPA. **Folder Embrapa Agroenergia**. 2021. Available from: https://www.embrapa.br/agroenergia/publicacoes. Visited on: 23 Apr. 2024.

74 PRATES, C. P. T.; PIEROBON, E. C. Formação do Mercado de Biodiesel no Brasil. pt. **BNDES Setorial**, v. 25, p. 39–64, 2007.

75 BIODIESELBR.COM. Frente do biodiesel vai ser relançada nessa próxima quarta-feira. **BiodieselBR**, Mar. 2023. Available from: https://www.biodieselbr.com/noticias/regulacao/politica/frente-do-biodiesel-vai-ser-relancada-nessa-proxima-quarta-feira-200323. Visited on: 16 Oct. 2023.

76 CONGRESS, N. **Frente Parlamentar Mista do Biodiesel - FPBio**. Mar. 2023. Available from: https://www.camara.leg.br/internet/deputado/frenteDetalhe.asp?id=54340. Visited on: 16 Oct. 2023.

77 BOSCHMA, R. Proximity and Innovation: A Critical Assessment. en. **Regional Studies**, v. 39, n. 1, p. 61–74, Feb. 2005. ISSN 0034-3404, 1360-0591. DOI: 10.1080/0034340052000320887.

List of biodiesel producers sent to IBGE

Company	CNPJ
ADM DO BRASIL LTDA.	02.003.402/0024-61
ADM DO BRASIL LTDA.	02.003.402/0046-77
AGROPAULO AGROINDUSTRIAL S.A.	05.373.212/0009-95
ALIANÇA BIOCOMBUSTÍVEL LTDA.	10.737.181/0001-97
AMAGGI EXPORTAÇÃO E IMPORTAÇÃO LTDA.	77.294.254/0055-87
AMAZONBIO - INDÚSTRIA E COMÉRCIO DA AMAZÔNIA LTDA.	08.794.451/0001-50
BE8 S.A	07.322.382/0001-19
BE8 S.A	07.322.382/0004-61
BIANCHINI S/A - INDÚSTRIA, COMÉRCIO E AGRICULTURA	87.548.020/0002-60
BINATURAL BAHIA LTDA.	37.880.187/0001-75
BINATURAL INDÚSTRIA E COMÉRCIO DE ÓLEOS VEGETAIS S/A	07.113.559/0001-77
BIO ÓLEO INDÚSTRIA E COMÉRCIO DE BIOCOMBUSTÍVEL LTDA.	08.387.930/0001-51
BIO VIDA PRODUÇÃO E COMÉRCIO DE BIODIESEL LTDA.	08.772.264/0001-75
BIONORTE INDÚSTRIA E COMÉRCIO DE BIODIESEL LTDA.	08.080.422/0001-26
BIOPAR PRODUÇÃO DE BIODIESEL PARECIS LTDA.	08.684.263/0001-79
BOCCHI INDÚSTRIA E COMÉRCIO DE CEREAIS LTDA.	02.987.873/0010-56
BUNGE ALIMENTOS S/A	84.046.101/0543-66
CAIBIENSE GRAN VITA LTDA.	75.817.163/0007-56
CAMERA AGROALIMENTOS S.A	98.248.644/0026-56
CARAMURU ALIMENTOS S/A	00.080.671/0003-71
CARAMURU ALIMENTOS S/A	00.080.671/0021-53
CARAMURU ALIMENTOS S/A	00.080.671/0026-68
CARGILL AGRÍCOLA S/A	60.498.706/0294-81
CEREAL COMÉRCIO EXPORTAÇÃO E REPRESENTAÇÃO AGROPECUÁRIA S.A.	00.012.377/0001-60
CESBRA QUÍMICA S/A	08.436.584/0001-54
COCAMAR MÁQUINAS AGRÍCOLAS LTDA.	02.213.491/0011-56
COFCO INTERNATIONAL BRASIL S.A.	06.315.338/0228-64
DELTA BIOCOMBUSTÍVEIS INDÚSTRIA E COMÉRCIO LTDA.	11.513.699/0001-00
DELTA CUIABÁ PRODUTORA DE BIOCOMBUSTÍVEIS LTDA.	11.652.509/0001-35
FÊNIX COMPLEXO INDUSTRIAL S.A	35.367.818/0002-02
FIAGRIL LTDA.	02.734.023/0008-21
FUGA COUROS S.A.	91.302.349/0016-10
GRANOL INDÚSTRIA, COMÉRCIO E EXPORTAÇÃO S/A	50.290.329/0026-60
GRANOL INDÚSTRIA, COMÉRCIO E EXPORTAÇÃO S/A	50.290.329/0061-43
GRANOL INDÚSTRIA, COMÉRCIO E EXPORTAÇÃO S/A	50.290.329/0084-30
IPÊ BIOCOMBUSTÍVEL LTDA.	08.382.761/0001-67
JATAÍ AGROINDÚSTRIA DE BIOCOMBUSTÍVEL LTDA.	07.445.656/0001-67
JBS S/A	02.916.265/0133-00
JBS S/A	02.916.265/0280-99
LAR COOPERATIVA AGROINDUSTRIAL	77.752.293/0124-47
MINERVA S/A	67.620.377/0047-05
OLEOPLAN NORDESTE INDÚSTRIA DE BIOCOMBUSTÍVEL LTDA.	13.463.913/0003-58
OLEOPLAN PARÁ INDÚSTRIA DE BIOCOMBUSTÍVEL LTDA.	39.796.014/0001-07
OLEOPLAN RONDÔNIA INDÚSTRIA DE BIOCOMBUSTÍVEL LTDA.	36.015.262/0002-58
OLEOPLAN S/A – ÓLEOS VEGETAIS PLANALTO	88.676.127/0002-57
OLFAR S.A. ALIMENTO E ENERGIA	91.830.836/0064-52
OLFAR S.A. ALIMENTO E ENERGIA	91.830.836/0006-83
OLFAR S.A. ALIMENTO E ENERGIA	91.830.836/0040-85
PETROBRAS BIOCOMBUSTÍVEL S.A	10.144.628/0003-86
PETROBRAS BIOCOMBUSTÍVEL S.A	10.144.628/0004-67
POTENCIAL BIODIESEL LTDA.	12.613.484/0001-23
PRISMA COMERCIAL EXPORTADORA DE OLEOQUÍMICOS LTDA.	09.267.863/0006-09
PRODUTOS ALIMENTÍCIOS ORLÂNDIA S/A - COMÉRCIO E INDÚSTRIA	53.309.845/0001-20
SEARA ALIMENTOS LTDA.	02.914.460/0327-88
TAUÁ BIODIESEL LTDA.	08.079.290/0001-12
TRÊS TENTOS AGROINDUSTRIAL S/A	94.813.102/0050-58
TRÊS TENTOS AGROINDUSTRIAL S/A	94.813.102/0017-37
UNIÃO INDÚSTRIA E COMÉRCIO DO PARÁ LTDA.	30.937.909/0001-31
UNIBRAS INDÚSTRIA E COMÉRCIO DE BIOCOMBUSTÍVEL LTDA	33.931.174/0001-27
USINA BARRALCOOL S/A	33.664.228/0001-35
BIO BRAZILIAN ITALIAN OIL INDUSTRIA, COMERCIO E EXPORTACAO DE BIOCOMBUSTIVEIS L	08.429.269/0001-08
BIO PETRO PRODUCAO E COMERCIALIZACAO DE BIOCOMBUSTIVEIS LTDA.	07.156.116/0001-63
BIOCAMP INDUSTRIA, COMERCIO, IMPORTACAO E EXPORTACAO DE BIODIESEL LTDA.	08.094.915/0001-15
BIOCAPITAL PARTICIPACOES S.A.	07.814.533/0001-56
BIOPAR - BIOENERGIA DO PARANA LTDA.	07.922.068/0001-77
COFCO INTERNATIONAL BRASIL S.A.	06.315.338/0026-77
COFCO INTERNATIONAL GRAINS LTDA.	29.332.398/0002-26
COMPANHIA PRODUTORA DE BIODIESEL DO TOCANTINS	07.913.930/0001-85
PETROBRAS BIOCOMBUSTIVEL S/A	10.144.628/0002-03
SPBIO INDUSTRIA E COMERCIO DE BIODIESEL E OLEOS VEGETAIS LTDA.	05.164.528/0001-10
SSIL SOCIEDADE SALES INDUSTRIAL LTDA.	24.748.311/0001-00