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Kingdom of the Netherlands

The Brazilian Landscape of Science, Technology, and Innovation in Semiconductors

Center for Strategic Studies and Management
Science, Technology and Innovation

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A social organization supervised by the Ministry of Science, Technology, and Innovation (MCTI)

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Foreword

The Netherlands Innovation Network, part of the Ministry of Economic Affairs of the Netherlands, actively works to strengthen the bilateral science, technology, and innovation relationship between the Netherlands and Brazil. As part of this mandate, we seek to collaborate with key Brazilian stakeholders to investigate scientific, technological, and innovative developments in critical technology areas. Semiconductor Technologies represents one of these strategic areas, and as head of the Netherlands Innovation Network in Brazil, I am pleased that we have developed a partnership with the Center for Strategic Studies and Management (CGEE) to conduct a comprehensive landscape mapping of current policy, R&D and innovation developments in Brazil's semiconductor sector. This report will undoubtedly contribute to furthering science, technology, and innovation relationships between the Netherlands, Europe, and Brazil.

Robert Thijssen

Counselor for Innovation, Technology and
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The Brazilian Landscape of Science, Technology, and Innovation in Semiconductors

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1. Introduction:
Brazil's Evolving Semiconductor Landscape

The semiconductor industry represents a critical foundation for technological sovereignty and economic development in the global digital economy. As essential components in virtually all modern electronic devices, semiconductors drive innovation across telecommunications, healthcare, transportation, and energy sectors, among many others. In this context, understanding Brazil's position and potential in the semiconductor value chain offers valuable insights for strategic planning and international collaboration.

The semiconductor ecosystem comprises a complex network of interconnected business models and specialized entities. These include Integrated Device Manufacturers (IDMs) that vertically integrate design and manufacturing processes; Original Equipment Manufacturers (OEMs) that assemble final products using semiconductor components; fabless companies that focus exclusively on design while outsourcing production; Design Houses (DHs) that specialize in chip and system design; and foundries that manufacture chips according to provided specifications without developing proprietary designs.

The semiconductor value chain encompasses a complex series of specialized activities – from design and front-end fabrication to packaging, testing, and system integration. Brazil has strategically positioned itself in segments that align with its existing industrial capabilities and technological expertise while developing policies to strengthen areas of relative weakness. This approach acknowledges global realities where semiconductor manufacturing has become increasingly concentrated, capital-intensive, and technologically specialized.

The Brazilian electrical and electronics sector continues to face significant challenges, as evidenced by an USD 18.1 billion trade deficit in the first half of 2023. Though semiconductor imports decreased by 20% compared to the same period in 2022, they remained the leading category of foreign purchases at USD 2.7 billion. This reduction, while notable, highlights Brazil's ongoing dependence on high-value industrial components like semiconductors. The COVID-19 pandemic exposed vulnerabilities in Brazil's semiconductor supply chain, particularly its reliance on Asian imports. Without a complete domestic semiconductor value chain, critical sectors including automotive and electronics manufacturing experienced production constraints due to chip shortages and increased costs. These disruptions underscored the strategic importance of strengthening national semiconductor production capabilities.

Brazil stands at a pivotal moment in its semiconductor industry development trajectory. With established capabilities in specific value chain segments – particularly in design, back-end manufacturing, and specialized applications – the country has created a foundation for growth while facing significant challenges in establishing a comprehensive domestic semiconductor ecosystem. Brazil's distinctive combination of academic research strengths, emerging industrial capabilities, and strategic policy initiatives presents both opportunities and complexities for stakeholders seeking to engage with this evolving technological landscape.

The country's semiconductor ecosystem features several distinctive characteristics:

- Research capabilities are concentrated in key universities and research centers, particularly in the Southeast and Southern regions, with specialized expertise in areas such as power electronics, analog circuits, and embedded systems

- Industrial activities focused primarily on back-end operations, system integration, and specialized applications in sectors including automotive, consumer electronics, and energy

- Policy frameworks evolving from the Information Technology Law (1991) through PADIS initiatives and more recent industrial strategy programs

- Educational institutions developing specialized curriculum and research programs to support workforce development in this technical field

This report aims to comprehensively assess Brazil's semiconductor science, technology, and innovation landscape through three key dimensions: policy and regulation, public and private investments, and research, development, and innovation capabilities (Figure 1). By examining each dimension systematically, the analysis seeks to identify opportunities for international collaboration that leverage Brazil's existing strengths while addressing its technological and industrial challenges.

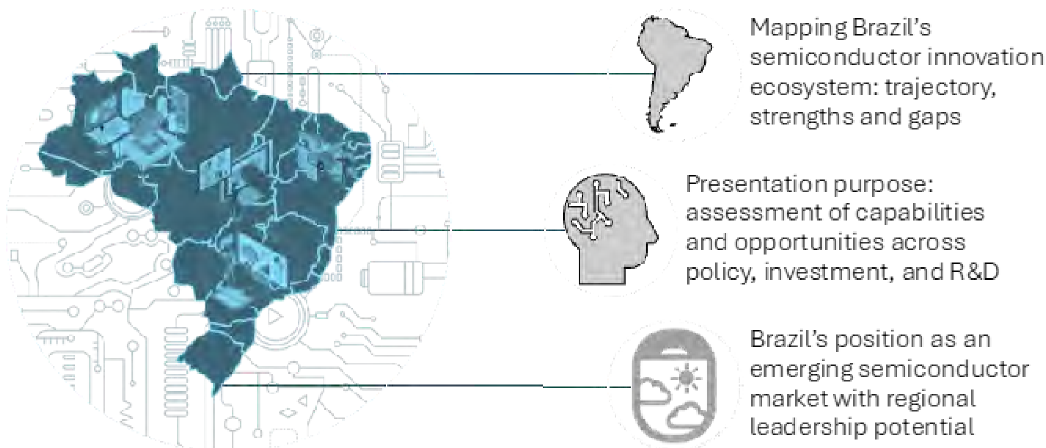

Figure 1. Brazil's Semiconductors Landscape: Report Context and Objectives.

The methodological approach combines analysis of policy frameworks and regulatory developments, compilation of investment data from public and private sources, and assessment of research outputs including regional innovation centers, scientific publications, and patent activities. This multi-faceted approach provides a foundation for understanding Brazil's current position and potential trajectory in the global semiconductor ecosystem.

Brazil's strategic interests in semiconductor development reflect broader objectives including technological autonomy, industrial competitiveness, and integration into global value chains. The country's approach acknowledges both the challenges of competing in capital-intensive front-end manufacturing and the opportunities in specialized design, back-end operations, and emerging applications that align with national priorities in areas such as renewable energy, electric mobility, and digital infrastructure.

2. Semiconductors Policy and Regulation in Brazil

2.1. The Evolution of Brazil's Semiconductors Legislation

Brazil has developed a progressive framework of policies and regulations aimed at fostering its semiconductor industry over the past three decades (**Figure 2**). This evolution reflects the country's recognition of semiconductors as a strategic sector for technological independence and economic development.

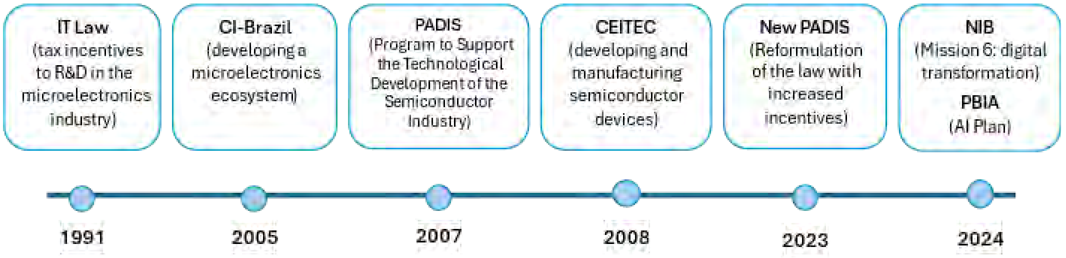

Figure 2. The Evolution of Brazil's Semiconductors Legislation in the Past Thrity-Five Years.

The timeline shown above highlights key milestones in Brazil's semiconductor policy development, beginning with the Information Technology Law in 1991 and advancing through increasingly specialized initiatives. This progression demonstrates Brazil's commitment to adapting policies to the changing needs of the semiconductor sector while acknowledging the challenges of competing in a global market dominated by established players.

2.2. Brazil's Approach to Semiconductors Policies

Brazil occupies a unique position in the global semiconductor landscape. Despite being one of the world's largest IT consumer markets, its semiconductor components industry remains relatively modest, with limited export capacity. This situation reflects broader trends in the Brazilian industry, with few signs of productive differentiation in the semiconductor value chain.

The multinational companies operating in Brazil typically implement less capital-intensive stages of semiconductor production, primarily motivated by tax benefits conditioned on local R&D investments. This stands in contrast to the global semiconductor industry's highly specialized nature, where countries have established distinctive competencies: the United States in logic chip design, South Korea in memory technologies, Taiwan in advanced manufacturing, Japan in materials and equipment, and the Netherlands in lithography systems. China has recently pursued a more comprehensive strategy, moving away from specialization in specific stages to develop capabilities across the entire value chain. This shift has been accelerated by international trade restrictions, pushing China toward greater self-sufficiency despite significant technological challenges.

Despite decades of federal government efforts, Brazil's position in this global context remains peripheral. This situation is not unique to semiconductors but reflects broader challenges in the country's electronics industry. While public policies implemented between the 1990s and 2000s included important sectoral initiatives for semiconductors, they have faced limitations in creating a comprehensive ecosystem. Nevertheless, these governmental efforts did establish a domestic foundation for semiconductor research, development, and innovation, particularly in specific segments of the value chain and specialized areas.

The following sections detail the key policies aimed at fostering research, development, and local production of semiconductors in Brazil, with a focus on reducing foreign dependence and increasing national competitiveness in the semiconductor value chain.

2.3. Key Policy Instruments for the Semiconductor Sector

2.3.1. The Informatics Law (ICT Law)

The Information Technology (or Informatics) Law (Law No. 8,248/1991) represents Brazil's first significant policy intervention affecting the semiconductor sector. This legislation established tax incentives for companies investing in research and development (R&D) in information and communication technologies (ICT), including semiconductors.

Having undergone several modifications since its creation, the IT Law remains one of Brazil's longest-standing instruments for stimulating innovation and manufacturing in the electronics sector. To align with World Trade Organization (WTO) rules, the incentive mechanism evolved from tax exemptions to financial credits proportional to R&D investments, which companies can use to offset tax obligations.

Currently known as the ICT Law (Lei de TICs), its primary benefit consists of providing financial credits calculated based on the gross turnover from incentivized products. Companies receiving these benefits must make mandatory R&D investments, with a portion directed toward partnerships with science and technology institutions. This requirement strengthens academia-industry integration and includes special provisions to promote socioeconomic development in the historically underserved North, Northeast, and Midwest regions.

From 1994 (its first complete year of implementation) to 2021 (the most recent year with public data available), the Informatics/ICT Law generated R$206 billion in tax exemptions. This represents nearly 70% of all Brazilian tax incentives for research, development, and capacity building in science, technology, and innovation during this period. Between 2007 and 2021, it provided 2.5 times more tax relief than the R&D tax incentive program Lei do Bem. Although the ICT Law encompasses all electronic subsectors rather than focusing exclusively on semiconductors, it serves as the primary source of public financial incentives for the semiconductor industry.

2.3.2. Program to Support the Technological Development of the Semiconductor Industry (PADIS)

To address the specific challenges of the semiconductor sector, Brazil established the *Program to Support the Technological Development of the Semiconductor Industry* (PADIS) through Law No. 11.484/2007. This program represented a landmark event by focusing directly on developing Brazil's semiconductor industry's competitiveness.

PADIS provides substantial tax incentives, including exemptions for companies investing in semiconductor and display production. Participating companies must allocate a percentage of their turnover to R&D activities, often in partnership with Brazilian science and technology institutions. The program aims to enhance the national industry's competitiveness, strengthen the production chain, and foster technological innovation. To participate, companies must have their projects approved by the Ministry of Science, Technology and Innovation (MCTI) and regularly report on their R&D investments.

PADIS has been instrumental in establishing component manufacturing operations that supply the domestic market, particularly for smartphone memory chips. The tax benefits have made Brazilian production economically viable, attracting multinational investments and creating skilled jobs. Despite these incentives, the program continues to face structural challenges, including the limited scale of domestic production and persistent dependence on imports. While this represents economic progress, Brazil's technological role in the global semiconductor industry remains modest, with a few exceptions in specialized design for niche applications.

In 2023, PADIS underwent significant reformulation, resulting in the New PADIS or Brazil Semiconductors Program (*Brazil Semicon*). This updated framework expands tax incentives and includes additional benefited inputs, such as components for solar panel production **(Figure 3).** The program now features a management council to oversee implementation and authorizes BNDES and FINEP to develop financial support instruments, including credit lines and securities subscriptions.

Old PADIS (Law n° 11.484/2007)

- **Objective**: Encourage R&D in the semiconductor and display sector
- **Beneficiaries**: companies producing semiconductors, displays, and electronic components
- **Incentives**: Reduction of import tax, IPI and PIS-COFINS to 0% for semiconductor and chip production
- **Requirements:** Companies must invest a minimum % of their gross revenue in R&D
- **Impact**: Attracted investments for local production but faced challenges due to global competition and a lack of advanced infrastructure in Brazil
- **Duration**: Until 2026

New PADIS (Decree n° 11.456/2023)

- **Objective**: Expand tax incentives to the photovoltaic sector, strengthening semiconductor and solar energy industries
- **Beneficiaries**: Companies producing photovoltaic cells and panels
- **Incentives**: Maintains previous tax incentives and extends them to the solar energy sector
- **Requirements**: Mandates R&D investments with enhanced monitoring and transparency (conditionalities)
- **Impact**: Reduces external dependence while promoting the semiconductor industry and green economy
- **Duration**: 2029, with possible extension to 2073

Figure 3. Comparison between PADIS and the New PADIS.

2.3.3. Professional Training Initiatives: *CI-Brasil (2005) and CI-Inovador (2024)*

Launched in 2005, the CI-Brasil (Integrated Circuits Brazil) Program represents yet another critical initiative to develop Brazil's semiconductor capabilities, focusing on human capital and design capacity. Coordinated by the MCTI in collaboration with academic institutions and industry partners, the program prioritizes training professionals in integrated circuit design and strengthening the national semiconductor ecosystem.

The program operates along three strategic axes:

a) **Stimulating Economic Activity in Integrated Circuit (IC) Design:** Since 2005, the program has supported the creation and development of 20 Design Houses distributed across Brazil, building the foundation for a domestic IC design industry.

b) **Expanding the Training of Integrated Circuit Designers:** In 2008, the National Integrated Circuit Designer Training Program was established in partnership with Cadence Design

Systems. This initiative includes two Training Centers (CT1 and CT2), which have prepared more than 500 IC designers since inception.

c) Promoting the Creation of a National Semiconductor Industry: This axis has attracted international companies such as Toshiba Microelectronics to establish design operations in Brazil. It also supported the National Center for Advanced Electronic Technology (CEITEC) and initiatives like the Micron HT joint venture between South Korea's Hana Micron and a Brazilian consortium to establish semiconductor manufacturing facilities in Rio Grande do Sul.

Building on CI-Brasil's foundation, the CI-Inovador (Integrated Circuits Innovator) program was launched in 2024 to address contemporary workforce challenges in the semiconductor sector. This initiative focuses on:

- Training professionals in semiconductors and microelectronics with practical skills.
- Facilitating technical visits by Brazilian students to institutions abroad.
- Offering 250 spots in its first phase, with 30% reserved for women.
- Providing a monthly scholarships of R$ 5,000 for six-month training periods, plus government-funded international travel.

2.3.4. CEITEC (National Center for Advanced Electronic Technology)

CEITEC S.A., a state-owned company created in 2008 and established in Porto Alegre (state of Rio Grande do Sul), represents Brazil's most ambitious institutional initiative to boost the semiconductor sector. Focused on the design and production of integrated circuits, CEITEC was established to strengthen national technical capabilities and improve Brazil's position in the global semiconductor value chain.

Despite facing administrative and financial challenges, the company has served as a center for technological innovation. CEITEC's contributions to Brazil's semiconductor sector include the development of technical expertise. However, many highly qualified designers left CEITEC and joined international companies after the organization entered liquidation proceedings in 2020.

A notable turning point came in 2023, with efforts to reverse the liquidation process. The newly elected government then initiated steps to restore CEITEC's operational capacity, including recomposing its technical staff and developing plans to meet public and private sector demands. This restructuring involves R$ 220 million in investments from 2024 to 2026, with a strategic pivot toward silicon carbide semiconductors for clean energy applications, particularly for electric vehicles and renewable energy systems.

2.3.5. New Industry Brazil (NIB) and Brazil's AI Plan (PBIA)

Brazil's newest industrial policy framework, New Industry Brazil (NIB), covers the period 2024-2033 and includes semiconductors as a strategic priority. Within its mission-oriented structure, Mission 4 focuses on the Digital Transformation of Industry to Increase Productivity, addressing several semiconductor-related challenges:

- Training and qualifying the workforce in ICTs and semiconductors across basic and higher education.
- Fostering coordination and collaboration around national priorities.
- Promoting the adoption of national digital platforms across economic sectors.

• Increasing investments in innovation and internationalization to modernize ICT infrastructure and boost exports.

• Reducing dependence on imported solutions by strengthening domestic hardware development.

As part of this mission, NIB aims to strengthen production chains in semiconductors, industrial robots, and advanced digital products and services. A key objective is reducing Brazil's technological dependence on nano and microelectronic products, thereby strengthening the domestic ICT industrial chain.

Complementing these efforts, the Brazilian AI Plan (PBIA), announced in July 2024, aligns with and directly contributes to NIB's goals. In what concerns Brazil's semiconductor ambitions, a key PBIA action aims to establish international partnerships for the development of supercomputing nodes and machine learning accelerators. This initiative seeks to reduce dependence on foreign technology in critical AI hardware and enhance national research and development capabilities, thus contributing to positioning Brazil as a global partner in AI innovation.

2.4. Concluding Remarks on Semiconductors Policy and Regulation in Brazil

Brazil's semiconductor policy framework has evolved strategically since 1991, establishing increasingly robust support systems for domestic capabilities development. The progression from the IT Law through PADIS to its 2024 reformulation demonstrates Brazil's commitment to adapting policies to changing industry needs, particularly with the recent expansion into photovoltaic technologies.

CEITEC represents both challenge and opportunity – while facing operational difficulties by 2020, its current restructuring with R$220 million in investments reflects a promising pivot toward silicon carbide semiconductors for clean energy applications, aligning with global sustainability trends. Professional development initiatives have matured from CI-Brasil's ecosystem-building approach to CI-Inovador's targeted international training program, showing recognition that human capital development is essential for creating competitive advantage in the semiconductor value chain.

The New Industry Brazil (NIB) framework and Brazilian AI Plan (PBIA) represent the latest evolution in this policy journey, with NIB prioritizing semiconductors within its digital transformation mission and PBIA establishing strategic international partnerships for advanced computing infrastructure (among other AI initiatives that contribute to not only NIB's digital transformation mission but also the other five missions). Together, these initiatives reflect Brazil's comprehensive approach to reducing technological dependence while positioning itself as a global innovation partner.

While these policy instruments and institutional initiatives reflect Brazil's long-term commitment to developing semiconductor capabilities, the country continues to face significant challenges in establishing a comprehensive ecosystem that can effectively compete in the global market. Future policy developments will likely focus on strengthening connections between academic research and industrial applications while identifying strategic niches where Brazil can develop distinctive competencies.

3. Public and Private Investments in Semiconductors in Brazil

3.1. Overview of Brazil's Commitment to the Semiconductor Sector

Brazil has made substantial commitments to developing its semiconductor industry through various public investment mechanisms and incentive programs. The government has allocated more than R$ 21 billion between 2024 and 2026 to stimulate the development of a domestic semiconductor ecosystem (**Figure 4**).

Figure 4. Overview of Brazil's R$ 21,4 billion Commitment (2024-2026) to Semiconductors.

The cornerstone of this investment strategy is the Brazil Semiconductors Program (New PADIS or Brasil Semicon), which represents a significant expansion of the previous Program to Support the Technological Development of the Semiconductor Industry (PADIS). Established by a presidential decree in March 2023 and signed into law in September 2024, Brasil Semicon allocates R$7 billion annually until 2026 in tax incentives specifically targeted at the semiconductor sector (equivalent to all ICT Law tax exemptions in 2021). These incentives aim to stimulate research, innovation, and production of semiconductors and related information and communication technologies, with applications spanning solar panels, smartphones, personal computers, and Industry 4.0 devices.

Brazil’s public investment framework combines several key elements:

- **Tax Incentives:** The primary mechanism under Brasil Semicon provides tax relief to qualifying companies engaged in semiconductor research, development, and production.

- **Direct Investments:** The Ministry of Science, Technology and Innovation (MCTI) announced a R$220 million investment to revitalize CEITEC (National Center for Advanced Electronic Technology), focusing on adapting the company’s infrastructure to produce silicon carbide semiconductors for clean energy applications and electric vehicles.

- **Targeted Funding Programs:** FINEP (Financier of Studies and Projects, Brazil’s innovation agency) launched the Mais Inovação Brasil – Semiconductors Program with R$100 million to support companies in research, development, and innovation projects, utilizing non-reimbursable funds from the National Fund for Scientific and Technological Development (FNDCT).

- **Regional Support:** The State of Rio Grande do Sul has allocated R$70 million to support R&D projects, technology development, and human resources training in the semiconductor sector through its State Semiconductor Program.

These investments align with the New Industry Brazil (NIB) program, which defines semiconductor development as a strategic priority for enhancing domestic industrial capacity and reducing technological dependence.

3.2. Public Semiconductor Investment Initiatives and Programs

The main public financial instruments supporting semiconductor projects in Brazil include tax incentives, specific credit lines, and direct investments. **Table 1** below highlights key public investment initiatives in the semiconductor sector.

Table 1. Public Calls and Semiconductors Projects

Date	Investment focus/ Call name	Description	Responsible entities	Topics	Investment (in reais)
12/2024	CEITEC (National Center for Advanced Electronic Technology)	Restructuring CEITEC's industrial plant to produce silicon carbide semiconductors	FNDCT/MCTI	Companies; Semiconductors	220.000.000
03/2024	Program BNDES Mais Inovação	Funding for ADATA in semiconductor production	MCTI, FINEP, MDIC, MCOM, BNDES	Companies; Semiconductors	290.000.000
01/2024	Mais Inovação Brasil – Semiconductors Program	Grants for innovative projects with a high technological risk	FINEP	Companies; Semiconductors	100.000.000
09/2023	Inova Semiconductors	Support for projects to train skilled workers in the microelectronics sector	FAPERGS, Rio Grande do Sul Department of Innovation, Science and Technology	Human Resources; Semiconductors	3.000.000
04/2024	TECHFUTURO Semiconductors Program	Encouraging collaboration between scientific institutions and companies in the semiconductor sector	FAPERGS, Rio Grande do Sul Department of Innovation, Science and Technology	Semiconductors; Cooperation	11.000.000

The five semiconductor initiatives, announced in 2023-2024 and to be executed from 2025 onwards, allocated R$604 million to semiconductor development. The largest funding commitment (R$290 million) is directed toward the BNDES *Mais Inovação Program supporting* ADATA's semiconductor production capabilities, followed by the R$ 220 million restructuring of CEITEC's industrial plant for silicon carbide semiconductor manufacturing.

The state of Rio Grande do Sul, where CIETEC is headquartered, is positioning itself as an emerging regional semiconductor hub, with two initiatives totalling R$ 14 million as part of their broader R$ 70 million planned investment in the sector. These programs – Inova Semiconductors (R$ 3 million) and TECHFUTURO Semiconductors Program (R$ 11 million) – focus on workforce development and strengthening academia-industry collaboration, respectively.

Beyond these specific programs, the National Bank for Economic and Social Development (BNDES) offers general credit lines to support technological innovation in the sector. These funding mechanisms are designed to address different aspects of the semiconductor value chain, from basic research and workforce development to production scaling and market integration.

The resumption of CEITEC's activities in 2024 represents a significant milestone in Brazil's semiconductor strategy. With R$ 220 million in investments planned for 2024-2026 (funded through FNDCT), CEITEC aims to adapt its infrastructure for the scale production of silicon carbide semiconductors. This specialized focus aligns with global trends toward high-performance power electronics for decarbonization processes and clean energy applications, particularly in electric vehicles and renewable energy systems.

The multi-faceted approach demonstrates Brazil's commitment to building a comprehensive semiconductor ecosystem that addresses both production capacity and the innovation pipeline necessary for long-term competitiveness in this strategic industry.

3.3. Private investment in Semiconductors in Brazil

Private investment in Brazil's semiconductor sector has shown promising growth, with the government projecting over R$ 24 billion in private semiconductor investments in the coming years. Implicitly, such a significant capital commitment would reflect an increasing confidence in the sector's development potential.

Several notable private investment initiatives illustrate this trend:

- **HT Micron:** R$ 100 million allocated to expand production capacity and innovate manufacturing processes for smartphone and tablet chips.

- **ADATA:** R$ 375 million investment for local production of three new semiconductor types designed for computers, servers, TVs, smartphones, and vehicles. Of this total, R$290 million is being provided through BNDES financing.

- **Zilia Technologies:** R$ 650 million earmarked to expand production capacity, broaden its product portfolio, and increase chip exports. As a Brazilian semiconductor factory, Zilia represents an important development in the domestic manufacturing landscape.

- **Simetrix Corporation:** Establishing Latin America's first semiconductor industry focused on producing ferroelectric memory chips, though the investment amount remains undisclosed.

These investments demonstrate strategic focus in specific areas. Brazil's investment landscape prioritizes semiconductor packaging (back-end operations) and design houses, while gradually developing front-end manufacturing capabilities through CEITEC's revitalization efforts. Private capital flows predominantly toward applications in renewable energy, electric vehicles, healthcare, and memory chips for electronic devices. Within the semiconductor value chain, Brazil has established a strategic position concentrated primarily on the packaging and production of memory chips for electronic devices, reflecting a deliberate approach to market positioning and technological development.

The private sector's investment patterns emphasize specialized niches rather than attempting to compete across the semiconductor value chain. This approach aligns with Brazil's existing industrial capabilities and research strengths while addressing domestic and regional market opportunities.

3.4. Concluding Remarks on Semiconductor Investments in Brazil

Brazil's approach to semiconductor investment represents a strategic national effort to establish technological sovereignty in a critical global industry. The combined R$ 21 billion public initiative and projected R$ 24 billion in private investment illustrate the scale of this commitment. The investment strategy balances several elements:

- **Tax incentives and direct funding:** Brasil Semicon and targeted FINEP programs provide complementary mechanisms to stimulate both research and commercial development.
- **Strategic focus areas:** Investments target memory chips, silicon carbide semiconductors for clean energy applications, and design capabilities rather than attempting to compete across the entire value chain.
- **Regional development:** Programs in states like Rio Grande do Sul complement national initiatives, creating regional semiconductor innovation clusters.
- **Public-Private synergy:** Government incentives are successfully mobilizing significant private sector participation, creating a multiplier effect on total semiconductor investment.

However, challenges remain in terms of transparency regarding the allocation and impact of these investments. While aggregate estimates like the MDIC's projection of R$ 24 billion in private investment provide a broad outlook, more detailed monitoring of specific projects and their outcomes would strengthen accountability and enable more effective policy refinement.

As Brazil continues implementing these investment programs, their success will depend on maintaining policy consistency, ensuring coordination between public and private stakeholders, and developing the specialized human capital necessary to support a growing semiconductor ecosystem. The current investment trajectory positions Brazil to develop specific competitive advantages within the global semiconductor landscape while reducing technological dependence in strategic applications.

4. Research, Development and Innovation (RD&I): Geographical Distribution and Sectoral Scope of RD&I Centers

4.1. Brazil's Semiconductor Research, Development and Innovation Infrastructure

Brazil's semiconductor RD&I landscape consists primarily of public and private non-profit research institutes (called "ICTs" in Brazil – *instituições de ciência e tecnologia:* science and technology institutions), packaging companies (both multinational and domestic), and a growing number of Design Houses. Recent years have seen increased investment in the photovoltaic technology segment, attracting foreign capital for panel assembly operations. However, the Brazilian semiconductor industry remains in its nascent stages, with approximately 40 active participants – significantly fewer than in countries where semiconductors represent a cornerstone industry.

Despite these challenges, continued investment in semiconductor innovation remains strategically essential for Brazil. Semiconductor technology has far-reaching implications across multiple sectors and increasingly influences global geopolitics, as evidenced by ongoing tensions in international trade relationships. Major global powers continue to make substantial investments in semiconductor development through policies such as the US CHIPS and Science Act, creating foundation-level support without which the industrial-scale R&D conducted by multinational corporations would be unfeasible.

Brazil's approach to semiconductor development has involved initiatives aimed at mitigating technological vulnerabilities and establishing a foothold beyond merely importing technologies. However, these efforts have yet to position the country as a significant player in the global semiconductor value chain.

4.2. Current Structure of Brazil's Semiconductor RD&I Ecosystem

The Brazilian semiconductor RD&I ecosystem is primarily focused on adjacent technologies rather than fundamental semiconductor development. Research activities emphasize applications, implementation, and integration of existing semiconductor technologies rather than front-end manufacturing capabilities. This approach reflects a strategic positioning that aligns with Brazil's industrial strengths and available resources.

The research landscape spans diverse areas, with embedded systems and software development dominating activities across 34 identified institutions, according to a survey by CGEE's Observatory of Digital Technologies (OTD). Other significant fields include nanotechnology, advanced sensors, and emerging technologies such as quantum computing. These research activities support applications in electronics, Internet of Things (IoT), solar energy, and various industrial sectors throughout the country.

Current efforts in Brazil predominantly concentrate on the final steps of semiconductor manufacturing, particularly packaging and testing, as establishing factories for front-end chip production (wafer fabrication) requires significantly higher capital investment. This focus represents a pragmatic approach to industry participation that leverages existing capabilities while building foundations for future growth.

4.3. Geographic Distribution of Brazil's Semiconductor RD&I Centers

The map in **Figure 5** reveals a distinctive dual-hub structure of the Brazilian semiconductor RD&I landscape, indicating the number of RD&I units in each state of the country, according to a survey by CGEE's Observatory of Digital Technologies (OTD). Manaus, in the state of Amazonas, hosts the largest concentration of RD&I facilities, primarily focused on embedded systems and applications. This cluster leverages the Manaus Free Trade Zone's industrial infrastructure and incentives. Meanwhile, established institutions in the South and Southeast regions specialize in more fundamental semiconductor research and development.

Geographical Distribution of Semicondutor Research Laboratories in Brazil

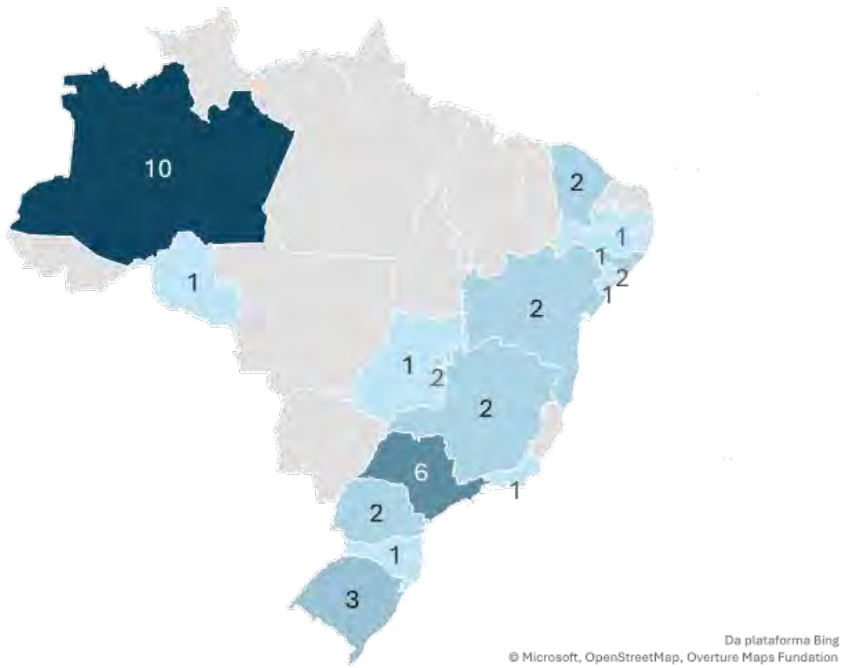

Figure 5. Geographical Distribution of Semicondutor Research Laboratories in Brazil.
Source: Observatório de Tecnologias Digitais (CGEE) - Observatory of Digital Technologies

The concentration of Science and Technology Institutions (ICTs) in Manaus, as shown in Figure 5, directly results from incentive programs like the Informatics Law and the Manaus Free Trade Zone. These tax advantages have encouraged companies to establish or relocate industrial operations to the region. With the Informatics Law facing potential expiration—threatening research, development and innovation (RD&I) activities outside the Free Trade Zone—migration to Manaus has accelerated. The political environment significantly impacts RD&I activities, particularly in the Free Trade Zone where tax incentives and sectoral policies determine ICT viability and competitiveness. A key structural challenge remains the lack of coordinated policy frameworks that would create greater synergy between national ICT legislation and Free Trade Zone regulations.

Manaus also struggles with a shortage of specialized talent, unlike established industrial and scientific hubs such as São Paulo. Recently established ICTs in Manaus face particular difficulty recruiting specialized local professionals—a requirement under Free Trade Zone incentives that paradoxically isolates these institutes and hinders talent acquisition. The regional disparity in qualified workforce availability is striking. While São Paulo benefits from university partnerships that facilitate network building and recruitment, Manaus must develop stronger collaborations with local educational institutions to address its workforce demands.

Although the ICT Law has enabled infrastructure development in Manaus, critics point to poor coordination between national and Amazonian regional legislation as a driver of corporate migration to the region, rather than organic growth.

This strategic regional specialization, spanning 15 of the 27 Brazilian states, creates a complementary national ecosystem. Universities and research institutes in the South (notably UFRGS and UFSC) and Southeast (particularly USP) concentrate on core semiconductor technologies, while facilities in the North and Northeast emphasize industrial applications and embedded systems development.

Rio Grande do Sul maintains significance through institutions like Unisinos, UFRGS, and companies including CEITEC and HT Micron. Santa Catarina contributes with several design houses and research at UFSC. São Paulo leverages its electronic equipment industry alongside research at USP, Unicamp, and specialized institutes such as the Eldorado Institute.

This geographic distribution reflects Brazil's strategic positioning in the semiconductor value chain, emphasizing implementation and integration capabilities rather than competing in capital-intensive chip manufacturing. Key entities like Eldorado Institute, SIDIA and CESAR support diverse industry applications nationwide, creating a network that spans multiple regions with complementary specializations.

4.4. The Brazilian Semiconductor Ecosystem: Technologies and Applications

The Brazilian semiconductor research and innovation ecosystem demonstrates particular technological strengths and application focuses that define its profile in the global landscape:

- Embedded systems predominance: The technological landscape is dominated by embedded systems, with 34 units dedicated to software and hardware embedded solutions (note that each research unit shown in the map above may focus on more than one semiconductor-adjacent technological area). This represents Brazil's most developed semiconductor-adjacent capability.

- Specialized research niches: Several specialized research areas have emerged as particular strengths, including nanotechnology (exemplified by CTNANO/UFMG, in the state of Minas Gerais), advanced sensors (iTRIAD, in Amazonas), digital fabrication (across five laboratories), and quantum computing (Venturus, also in Amazonas).

- Broad application focus: Research activities span traditional sectors such as telecommunications and electronics while extending into strategic fields including renewable energy, healthcare, and agribusiness. Most institutions serve multiple industries rather than specializing in a single domain.

- Integration-oriented approach: Brazil's semiconductor ecosystem emphasizes technology integration, reflecting its position in the global value chain. This approach concentrates on implementation, testing, and packaging rather than front-end chip manufacturing, with institutes like Eldorado Institute, SIDIA and CESAR supporting a wide range of applications across multiple locations in different states.

The technological profile of Brazil's semiconductor ecosystem positions the country as versatile but primarily application-oriented rather than focused on fundamental research or manufacturing. This strategic orientation leverages Brazil's strengths in software development and systems integration while building specialized capabilities in targeted areas.

4.5. Key Research and Innovation Centers in Brazil's Semiconductor Landscape

Several institutions stand out as central pillars of Brazil's semiconductor research and innovation ecosystem:

- **CTI (Renato Archer Information Technology Center):** This center maintains specialized laboratories that train professionals and conduct applied research in the semiconductor field. CTI plays a crucial role in connecting academic research with industrial applications.

- **CPQD (Center for Research and Development in Telecommunications):** Based in Campinas, CPQD has a long tradition of telecommunications and information technologies research, contributing significantly to microelectronics projects and knowledge transfer between academia and industry.

- **Eldorado Institute:** Focused on research, development, and innovation in hardware and software, the Eldorado Institute conducts projects in microelectronics and embedded systems that support Brazil's technological advancement.

- **CEITEC (Center of Excellence in Advanced Electronic Technology):** Located in Porto Alegre, CEITEC was established to enhance semiconductor design and manufacturing capabilities in Brazil. Despite structural changes over time, the company has played an important role in training specialized professionals and conducting chip design projects for specific applications, including RFID and electronic identification. Recent restructuring efforts aim to pivot CEITEC toward silicon carbide semiconductor production for clean energy applications.

- **University research centers:** Laboratories and research centers affiliated with public universities form a critical component of the ecosystem. The Integrated Systems Laboratory (LSI) at USP's Polytechnic School conducts research on integrated circuits, automation, and embedded systems. Additional significant contributors include research groups at UNICAMP, UFRGS (through PGMICRO, the Postgraduate Program in Microelectronics), and UFSC.

These ICTs, often working in partnership with funding agencies like FINEP and CNPq, contribute to expanding technical and scientific knowledge in microelectronics. The synergy between government initiatives, private enterprise, and academia has strengthened Brazil's innovation capacity in semiconductors, despite challenges related to manufacturing costs, global competitiveness, and specialized workforce development.

4.6. Semiconductor Workforce Development and Training

The development of qualified professionals represents a critical dimension of Brazil's semiconductor ecosystem. Several higher education institutions and research centers offer specialized training:

- **State University of Campinas (Unicamp):** Offers master's and doctoral programs in Electrical Engineering with research focuses on microelectronics, integrated circuit design (both digital and analog), and embedded systems.

- **University of São Paulo (USP):** Through the Polytechnic School (Poli-USP), research groups like LSI work on integrated circuit design, ASICs, FPGAs, and embedded systems, providing both formal education and research opportunities.

- **Federal University of Rio Grande do Sul (UFRGS):** Houses the nationally recognized Postgraduate Program in Microelectronics (PGMICRO), focusing on integrated circuit design and testing methodologies.

In addition to these academic programs, several universities offer lato sensu specialization courses addressing integrated circuit design and embedded systems to meet specific market demands. Training partnerships between science and technology institutions and companies, such as those involving CTI Renato Archer, further contribute to workforce development.

4.7. Concluding Remarks on the Brazilian semiconductor RD&I ecosystem

Brazil's semiconductor innovation ecosystem features a clear strategic positioning that leverages the country's strengths while acknowledging the realities of global semiconductor competition. Rather than attempting to compete directly with established global leaders in capital-intensive front-end manufacturing, Brazil has developed complementary capabilities in design, integration, and specialized applications.

The dual-hub structure centered on Manaus and the South/Southeast axis creates a geographically distributed but functionally integrated network. This arrangement supports specialization while enabling collaboration across regional boundaries. The concentration of academic research in institutions like USP, UNICAMP, and UFRGS provides a foundation of scientific knowledge, while application-focused centers in Manaus and other regions facilitate technology transfer and industrial implementation.

Brazil's emerging strengths in renewable energy applications, healthcare solutions, environmental technologies, and silicon carbide semiconductors present opportunities for strategic differentiation in the global marketplace. By focusing on these areas where domestic research shows particular promise, Brazil can develop specialized niches within the semiconductor value chain rather than competing across its entire breadth.

Future development of the Brazilian semiconductor ecosystem will require addressing persistent challenges, particularly the academic-industry disconnect and limited international integration. Strengthening pathways for commercializing university research and expanding collaborative networks with global research institutions could significantly enhance the ecosystem's productivity and impact. Targeted investments in workforce development, especially through programs like CI-Inovador, will be essential for building the human capital necessary to support continued growth and innovation.

5. Research, Development and Innovation (RD&I): Scientific Knowledge Base (Dissertations, Theses and Articles)

5.1. Graduate Research on Semiconductors in Brazil

5.1.1. The Production of Semiconductor Theses and Dissertations

Brazil has demonstrated a steady and significant expansion in academic research related to semiconductors over the past decade (**Figure 6**). An analysis of the CAPES Theses and Dissertations Catalog from 2013 to 2019 reveals that semiconductor-related research outputs more than doubled, increasing from 190 in 2013 to a peak of 423 in 2019, followed by a decline due to the impact of the Covid-19 pandemic. Contrary to master's dissertations, PhD theses on semiconductors peaked again in 2022, reaching 147 publications. Despite an increasing recognition of the strategic importance of semiconductor technologies for Brazil's industrial and technological development, graduate research publications on semiconductors represent less than 1% (theses) and than 0.5% (dissertations) in Brazil.

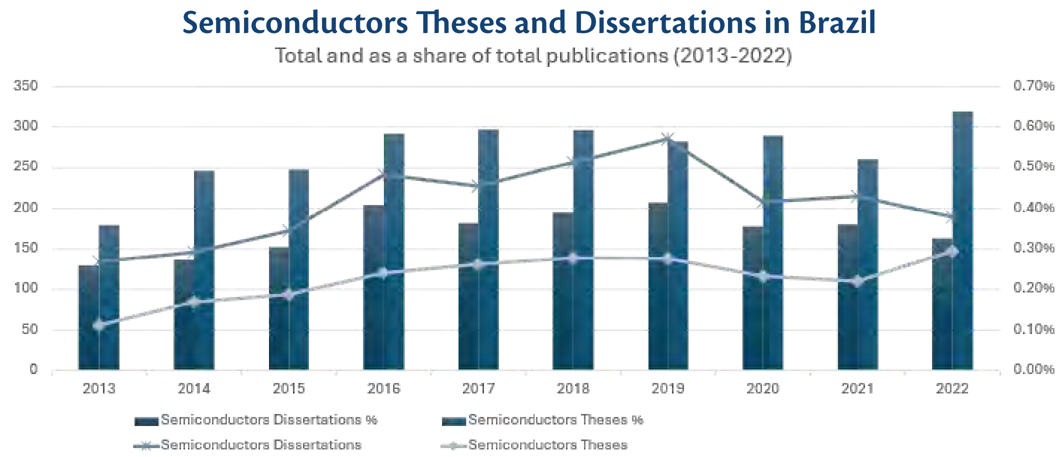

Figure 6. Graduate Semiconductors Research Production in Brazil.

The significant growth in theses compared to the more modest increase in dissertations highlights important trends in academic research related to semiconductors. This shift suggests an increasing focus on advanced, specialized research at the doctoral level. PhD research often drives innovation, leading to new theories, advanced materials, and novel device concepts. The rise in doctoral theses indicates that semiconductor research is becoming more complex, requiring deeper expertise and longer study periods.

In contrast, the slower growth in master's dissertations suggests that fewer students are conducting research at this level. This could mean that semiconductor research now demands more long-term, high-impact projects that are better suited for PhD studies. Alternatively, it might indicate that more master's students are transitioning directly into industry rather than pursuing academic research. Brazil is building semiconductor expertise, but translating this research into industrial innovation and economic impact requires strategic investment. The semiconductor industry has a high demand for skilled professionals, and many may choose to apply their knowledge in practical, industrial settings rather than continue in academia.

Another possible interpretation of this trend is increased collaboration between universities and the semiconductor industry. If fewer master's dissertations are being published, it may reflect a shift toward industry-driven research where students work on projects directly applicable to real-world challenges. This aligns with the growing global demand for semiconductors in fields such as power electronics, renewable energy, and automotive applications.

Additionally, the increase in PhD-level research might reflect that federal and state governments, universities, and private companies are investing more in cutting-edge semiconductor technologies. Areas such as wide-bandgap semiconductors (SiC, GaN), 2D materials (graphene, MoS_2), and quantum computing require extensive theoretical and experimental work typically conducted at the doctoral level. The data indicates that the field of semiconductor research is maturing, with a greater emphasis on long-term strategic advancements rather than short-term incremental improvements.

5.1.2. Leading States and Institutions in Semiconductor Theses and Dissertations Production

The analysis of thesis and dissertation production in semiconductor research reveals the leading institutions and states contributing to this field **(Figure 7)**.

Number of theses and dissertations on semiconductors by brazillian state (UF) per year

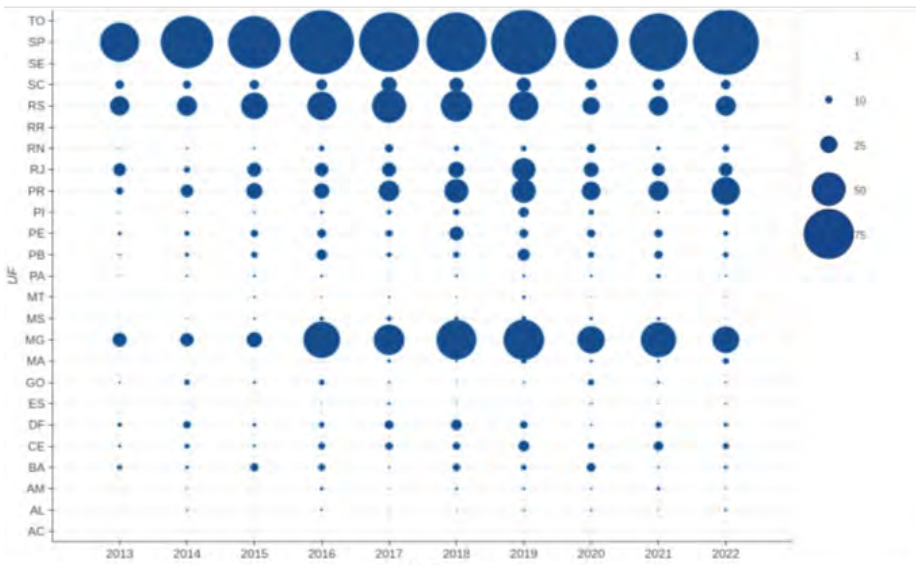

Figure 7. Number of theses and dissertations on semiconductors by Brazilian State (UF) (2013-2022)

São Paulo (SP) stands out as a major contributor to semiconductor graduate research activities, largely due to its size and the concentration of universities and research institutions driving innovation in the sector. Minas Gerais (MG) and Rio Grande do Sul (RS) demonstrated significant growth in patent filings up until 2019, reflecting the expanding role of these states in semiconductor research and development. Meanwhile, Paraná (PR) has shown steady growth over the years, indicating a consistent investment in technological advancements and intellectual property within the semiconductor field. This concentration in research output mirrors the location pattern of semiconductor RD&I centers, whereby university-related research units are mostly located in Southern and Southeastern states (with some also present in the Northeast region).

Indeed, the regional analysis reveals that the Southeast region (SP, MG, and RJ) generates nearly half (46.3%) of all semiconductors graduate research. The South region (RS, PR, and SC) substantially contributes 25.5% to the overall research output. In stark contrast, the North region demonstrates limited semiconductor research activity, despite the presence of RD&I units (dedicated to industrial applications) in Manaus (AM). Notably, the 2019-2020 period witnessed a widespread decline that impacted most research centers, suggesting that the challenges faced were systemic (the Covid-19 pandemic) rather than specific to regions.

Therefore, semiconductor-related graduate research in Brazil demonstrates a clear geographic concentration, with the Southeast, the South, and, to a lesser extent, the Northeast regions serving as the primary hubs for academic contributions. The research landscape is dominated by ten leading institutions – USP, UFRGS, UFSC, UNICAMP, UFMG, UFPE, UFSCAR, UNB, UFPR, and UFRJ – which collectively generate 38% of all semiconductor research output in the country. These institutions are crucial in advancing semiconductor technologies through fundamental and applied research, resulting in innovations in materials science, electronic devices, and power systems

This distribution highlights the concentration of semiconductor research in key academic and industrial hubs, reflecting regional expertise and investment in the field. The presence of leading institutions in these states suggests an emerging ecosystem for semiconductor innovation, fostering collaborations between universities, government agencies, and private companies. Understanding these trends helps in identifying strategic opportunities for further development and funding in semiconductor technologies.

5.1.3. Main Thematic Areas Covered by Semiconductor Theses and Dissertations

The research landscape of theses and dissertations reveals ten distinct dominant thematic areas:

a) **Power electronics & converters:** Focus on power converters, voltage, current, semiconductor switching, and DC-DC conversion.

b) **Thin films & spectroscopy:** Research on film properties, temperature effects, and Raman spectroscopy.

c) **Doped glasses & luminescence:** Semiconductors in glass materials, rare-earth doping, and luminescent properties.

d) **Chemical sensing & herbicide detection:** Studies on glyphosate detection and imprinted sensors.

e) **Quantum electronics & optical properties:** Semiconductor band structure, quantum effects, energy states, and magnetism.

f) **Photocatalysis & environmental applications:** TiO2 and ZnO-based photocatalysis, degradation of pollutants.

g) **Antimicrobial applications:** Antibacterial and antimicrobial coatings, silver nanoparticles, and hydroxyapatite-based materials.

h) **Nanomaterials & surface engineering:** Electrochemical properties of films, surface interactions, and nanostructured coatings.

i) **Quantum dots & nanoparticles:** Semiconductor quantum dots (QDs), fluorescence applications, and nanoparticle synthesis.

j) **Crystal structures & molecular complexes:** Molecular semiconductor materials, crystal structures, and organic-inorganic hybrids.

Research in semiconductors is characterized by its interdisciplinary nature, integrating multiple fields of knowledge and expertise. Among these, Electrical Engineering stands out as the most prominent area, underscoring the field's strong emphasis on semiconductor devices, circuit design, power electronics, and integrated systems. This focus highlights the critical role of semiconductor technologies in advancing modern electronics, enabling innovations across various industries and applications.

Physics also plays a significant role in semiconductor research. This is due to its fundamental contributions to understanding the electronic, optical, and quantum properties of semiconductor materials. Research in this area is crucial for advancing nanotechnology, quantum computing, and optoelectronic devices.

Another major field of research is Chemistry, which is closely related to the development of new semiconductor materials, thin-film deposition processes, and chemical properties of nanostructures. Chemistry plays an essential role in semiconductor fabrication techniques, including material synthesis and surface treatments.

Materials Science is also a key contributor, focusing on the structural, electrical, and mechanical properties of semiconductor materials. This area is critical for innovations in wide-bandgap semiconductors (SiC, GaN), 2D materials (graphene, MoS_2), and advanced nanostructures.

Lastly, the Computer Science area has a growing presence in semiconductor research. This is particularly relevant for topics such as hardware design, embedded systems, FPGA programming, and AI accelerators, which integrate software and semiconductor hardware for computational efficiency.

5.2. Academic Papers on Semiconductors in Brazil

5.2.1. Semiconductor Publication Trend

To analyze Brazilian scientific achievements in semiconductor subjects, data was collected for 21,159 articles from the Web of Science, spanning from as early as 1972 into 2025 (**Figure 8**). The number of Brazilian scientific publications in the Web of Science database has exhibited fluctuations over the years, with periods of rapid expansion followed by occasional declines (e.g., 2008, and after the pandemic). Some years experienced significant surges (like after 2012, and in the period of 2018-2021), reflecting heightened research activity, while others saw a slower pace of growth or even slight reductions. These variations could be attributed to factors such as increased funding for research, policy changes, or shifts in academic priorities. Despite the fluctuations, the overall trend suggests a sustained increase in scientific output, reflecting global trends.

Number of articles on semiconductors in the WoS with at least one author affiliated to a Brazilian institution

Figure 8. Academic Papers on Semiconductors in the Web of Science (WoS) Database with at least one author from a Brazilian Institution.

Since 2000, both Brazilian and global scientific production in semiconductors have shown fluctuations, with an overall decline in absolute numbers. The total number of world publications decreased by 42.8%, while Brazil's scientific output saw a 27.4% reduction after the pandemic.

Despite this decline, the proportion of Brazilian publications relative to the global total increased by 27.1%, indicating that Brazil's contribution to global research has remained resilient and even slightly expanded in relative terms, despite the overall contraction in scientific output (**Figure 9**).

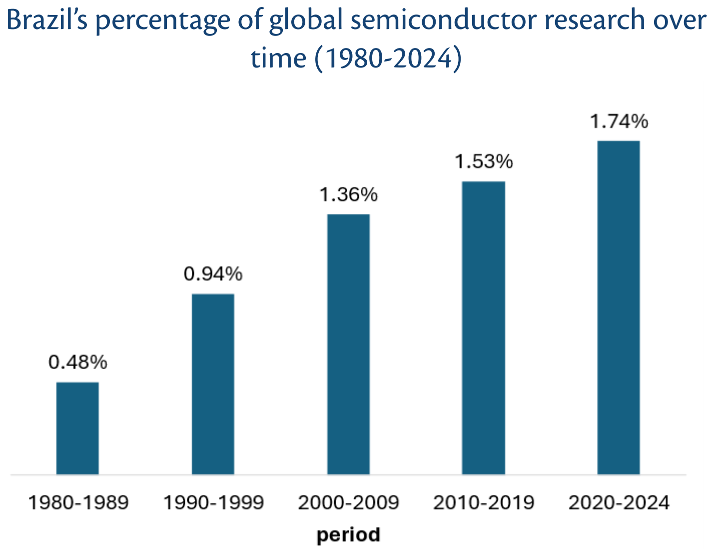

Figure 9. Brazil's Relative Contribution to Global Semiconductor Research.

Since 2000, both Brazilian and global scientific production in semiconductors have shown fluctuations, with an overall decline in absolute numbers. The total number of world publications decreased by 42.8%, while Brazil's scientific output saw a 27.4% reduction after the pandemic.

5.2.2. Semiconductor Academic Papers: Leading Institutions and Collaborations

Brazilian research in semiconductors has a moderate level of internationalization with a relative index around 0.4 (approximately 40% of Brazilian papers are done in collaboration with other countries). Since 2018, the internationalization of Brazilian semiconductor research has seen a strong upward trend, with international collaborations becoming increasingly prevalent **(Figure 10).**

Proportion of Brazilian Semiconductor articles co-authored internationally

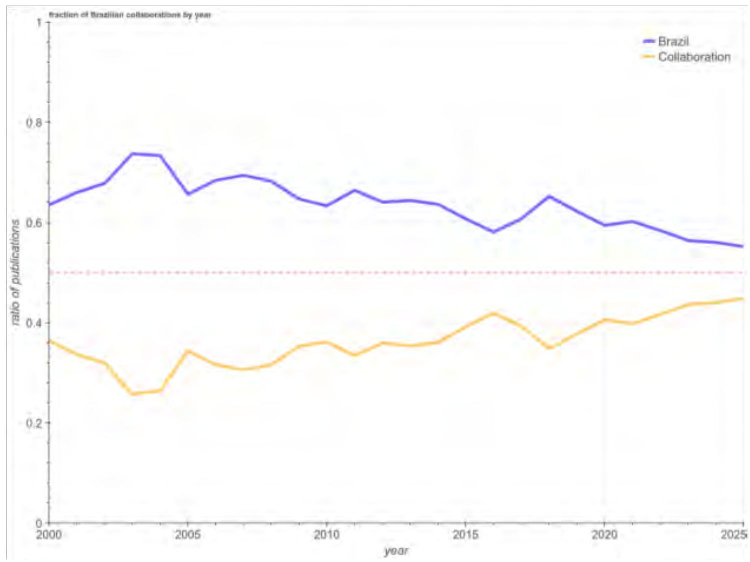

Figure 10. Proportion of Brazilian Articles on Semiconductor Co-authored Internationally.

A growing proportion of publications include international partnerships, reflecting Brazil's growing integration into global semiconductor research. These collaborations highlight the critical role of cooperation in advancing semiconductor technology, fostering knowledge exchange, and enhancing research impact. Brazilian semiconductor research has established robust international collaborations, with some countries presenting more significant positioning in the Brazilian academic collaboration network[1] (**Figure 11**). Brazil's top partner countries in semiconductor research, ranked by article co-authorships, include the USA (2,377), France (1,368), Germany (1,251), Spain (1,172), Portugal (974), England (693), India (650), Italy (606), Canada (526), China (475), and Argentina (456).

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[1] Network visualizations presented in this report were generated using VOSviewer, a software tool developed by Nees Jan van Eck and Ludo Waltman for constructing and visualizing bibliometric networks. For details on the methodology and application of the tool, see: van Eck, N.J. and Waltman, L., 2010. VOSviewer: A new tool for visualizing bibliometric networks. Journal of the American Society for Information Science and Technology, 61(2), pp.205–221. Available at: https://www.sciencedirect.com/science/article/pii/S2215016123003369.

Network of Brazilian International Collaboration on Semiconductor Scientific Papers

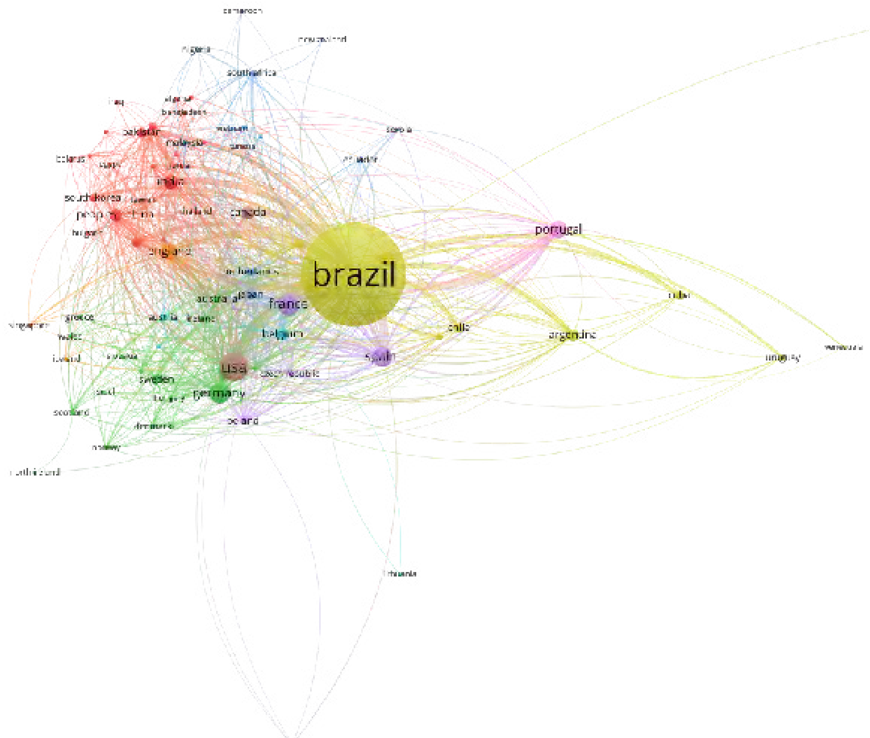

Figure 11. Network of Brazilian International Collaboration on Semiconductor Scientific Papers.

Note: The semantic network methodology analyzes relationships between objects—such as scientific articles and curricula vitae—by connecting elements (nodes) through edges that represent textual similarity. Node size corresponds directly to connectivity degree, indicating the number of established collaborations. The color coding of nodes identifies their respective country groupings, providing visual differentiation between collaborative clusters.

These leading countries in co-authored publications indicate strategic academic and scientific ties that support innovation in semiconductor technologies through shared expertise and joint research initiatives. These international collaborations have focused on various topics, including oxide films, electrochemical impedance spectroscopy, and semiconductor properties, demonstrating a strong emphasis on material science and device characterization. In Latin America, the partnership with Argentina has particularly highlighted anodic oxide layers and tungsten-based semiconductors, illustrating shared interests in developing novel materials for electronic applications.

In recent years, emerging collaborations have expanded Brazil's global research network to include new countries and research directions. Australia, Algeria, and Angola have begun appearing in co-authored publications, indicating a diversification of research partnerships. These newer collaborations contribute to topics such as thermoelectric materials, doped semiconductor systems, and semiconductor applications.

The involvement of countries like China and India has also increased, reflecting the global push toward advanced semiconductor manufacturing. This shift suggests that Brazil is not only consolidating its expertise in traditional semiconductor materials but also actively engaging in emerging fields such as thermoelectric applications and next-generation semiconductor structures, positioning itself within the evolving landscape of global semiconductor research.

The network of Brazilian and world organizations cooperating on semiconductor scientific papers shows a diverse and growing collaboration (**Figure 12**). In terms of institutions, the top ten Brazilian universities in the semiconductor collaboration network are:

a) Universidade de São Paulo (USP)

b) Universidade Estadual de Campinas (Unicamp)

c) Universidade Federal de São Carlos (UFSCar)

d) Universidade Federal Rio Grande do Sul (UFRS)

e) Universidade Federal de Minas Gerais (UFMG)

f) Universidade Federal de Pernambuco (UFPE)

g) Universidade Federal de Santa Catarina (UFSC)

h) Universidade de Brasília (UnB)

i) Universidade Federal do Ceará (UFC)

j) Universidade Federal do Rio de Janeiro (UFRJ)

Network of Brazilian and World Organizations Cooperating on Semiconductors Scientific Papers

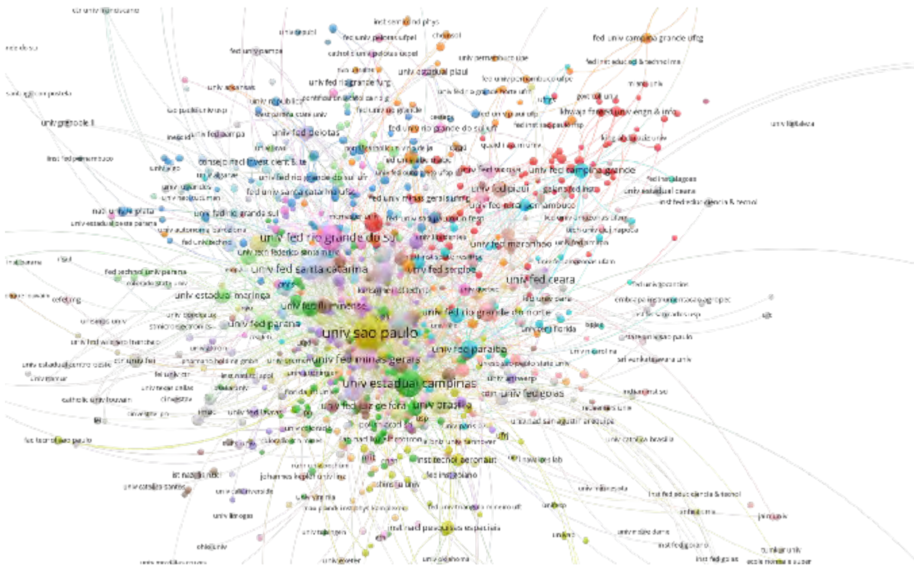

Figure 12. Network of Brazilian and World Organizations Cooperating on Semiconductors Scientific Papers.

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One prominent international organization collaborating extensively with the University of São Paulo (USP) in semiconductor research is Imec R&D. Imec plays a significant role in co-authoring scientific papers with the Brazilian university, fostering research partnerships, and advancing semiconductor technologies. The organization maintains research centers within several U.S. universities and operates a subsidiary in the Netherlands.

The main research subjects at Universidade de São Paulo (USP) in semiconductor research include X-ray diffraction, photocatalysis, TiO_2 (titanium dioxide), photoluminescence, and crystal structure analysis. These topics indicate a strong focus on advanced materials characterization, semiconductor-based energy applications, and optoelectronic properties of nanomaterials.

UNICAMP is highly engaged in quantum wells and doping techniques, which are essential for improving optoelectronic and nanoelectronic devices. While research at UFSCar spans various advanced semiconductor fields, UFMG shows a strong presence in zwitterionic complexes and surface engineering, indicating its involvement in advanced material synthesis. Meanwhile, UFC and UFPE contribute significantly to zone-folding effects and thin-film growth, which are critical for next-generation semiconductor materials.

The main research subjects at Universidade Federal do Rio Grande do Sul (UFRGS) in semiconductor research include FPGA (Field-Programmable Gate Arrays), photocatalysis, CMOS (Complementary Metal-Oxide-Semiconductor) technology, and TiO_2 (titanium dioxide) applications. These topics demonstrate a strong focus on reconfigurable electronics, semiconductor-based energy applications, and advanced materials for photonic and electronic devices.

The diversity in research topics across these institutions demonstrates Brazil's broad engagement in semiconductor innovation, ranging from fundamental material science to applied device engineering.

5.2.3. Semiconductor Academic Papers: Thematic Focus

Research areas in Brazilian semiconductor-related publications, therefore, encompass a diverse range of disciplines, reflecting the interdisciplinary nature of semiconductor technology (**Figure 13**). Among the most relevant fields, Materials Science stands out as the dominant area, followed by Electrical & Electronic Engineering, Physics Applied, and other fields, indicating a growing focus on applications related to advanced measurement techniques and energy-efficient semiconductor devices. These trends highlight the evolution of semiconductor research in Brazil, with an increasing emphasis on technological applications and new frontiers in nanotechnology and energy-related materials. The data on academic papers, therefore, confirms the sophistication of Brazilian semiconductor research implied by the graduate research analysis.

Research Fields of Brazilian Academic Papers on Semiconductors
(Grouped as WoS Categories)

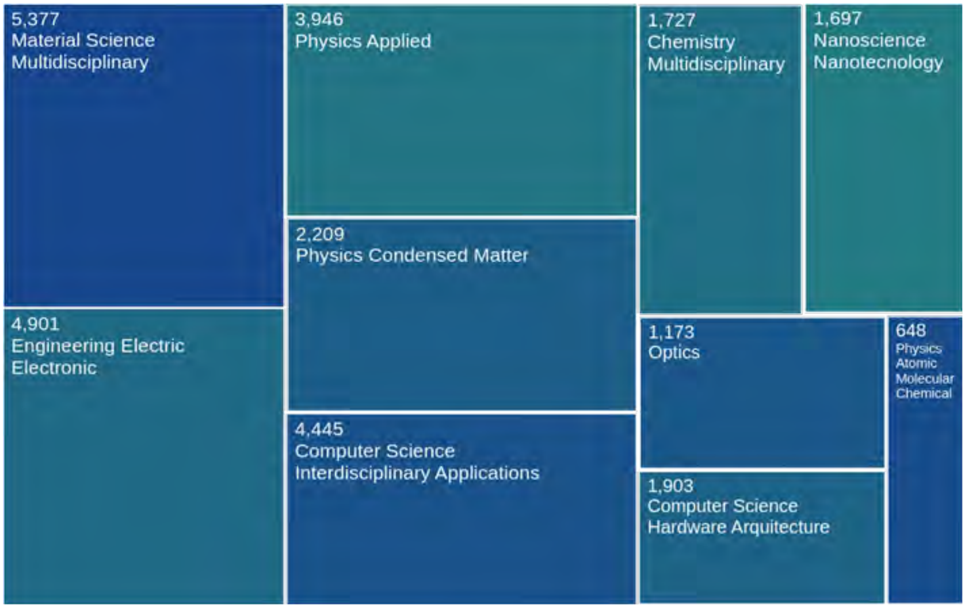

Figure 13. Research Fields of Brazilian Academic Papers on Semiconductors (Grouped as Wos Categories).

Analysis of the most frequent keywords in papers on semiconductors by Brazilian authors (**Figure 14**) reveals that Brazilian semiconductor research is strongly driven by Material & Device investigations, focusing on semiconductor materials, heterostructures, and thin films, which are crucial for enhancing the performance of electronic and optoelectronic devices. These research areas remain dominant, reflecting the continued interest in improving semiconductor fabrication techniques and exploring novel materials to push the limits of device efficiency.

Most Frequent Keywords in Semiconductor Papers by Brazilian Authors

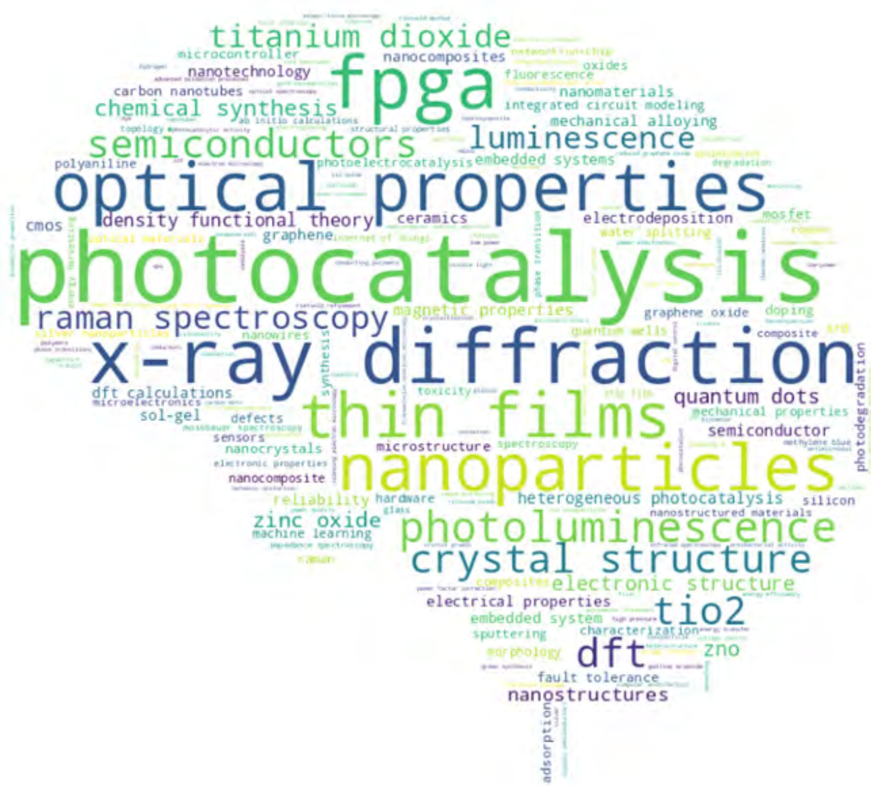

Figure 14. Most Frequent Keywords in Semiconductor Papers by Brazilian Authors.

Another growing trend is the increasing importance of Advanced Characterization Techniques, such as X-ray diffraction, which are essential for analyzing semiconductor properties at a fundamental level. These methods allow researchers to understand material composition, crystalline structures, and defects, aiding in the development of more reliable and efficient semiconductor technologies.

Additionally, there has been noticeable growth in Microwave & RF applications, which are critical for next-generation communication systems, including 5G and beyond. The demand for high-frequency, low-loss semiconductor materials has driven research in wide-bandgap semiconductors and high-speed electronic devices.

Lastly, the research landscape has seen an increasing focus on Specialized Semiconductor Structures, particularly semiconductor-semiconductor heterostructures. The trend toward bandgap engineering and novel material interfaces demonstrates efforts to enhance device performance, enabling applications in high-power electronics, quantum devices, and next-generation optoelectronics. This shift highlights Brazil's engagement with cutting-edge semiconductor research, aligning with global advancements in the field.

A thematic synthesis of the Brazil's academic research output highlights critical areas of development:

a) Power electronics and wide-bandgap semiconductors: Research on SiC and GaN devices has expanded, supporting high-efficiency applications in renewable energy, electric vehicles, and high-frequency communications.

b) Nanomaterials and thin-film technologies: Advances in surface engineering, doping techniques, and novel deposition methods have enhanced semiconductor performance in optoelectronics and sensors.

c) Quantum electronics and hardware: Research in bandgap engineering, heterostructures, and semiconductor quantum dots has positioned Brazil in strategic areas for next-generation computational and sensing technologies.

d) Photocatalysis and renewable energy applications: Studies on semiconductor-based photocatalysis (TiO_2, ZnO) for environmental applications align with the global push for sustainable technologies.

These research strengths position Brazil as a regional leader in semiconductor science, with the potential to bridge fundamental discoveries and applied innovations in industrial manufacturing.

5.3. Concluding Remarks on the Brazilian Semiconductor Scientific Knowledge Base

Brazil has established itself as Latin America's leader in semiconductor research, with its global contribution reaching nearly 2% by 2020-2021 and ranking 17th worldwide. This achievement reflects a consistent growth trajectory that accelerated after the PADIS program launch in 2007.

The research ecosystem is predominantly university-centered, with strong regional concentration in the Southeast (46.3%) and South (25.5%) regions. The top 10 institutions, led by USP, UFRGS, and UNICAMP, account for 38% of all semiconductor research output. This research spans multiple disciplines, with Electrical Engineering, Physics, and Chemistry collectively representing approximately 60% of all work.

Brazil's semiconductor research demonstrates strengths in environmental technologies and materials science, especially in photocatalysis for pollutant degradation, power electronics, and nanomaterials. While international collaboration exists with traditional semiconductor powerhouses, the network analysis reveals limited deep integration with global research centers.

Yet, the country faces critical challenges in semiconductor research, including limited research-to-industry translation, weak academia-industry connections, funding constraints, infrastructure gaps, fragmented international partnerships, and regional research concentration. These issues require targeted policies to transform scientific strengths into industrial competitiveness in strategic market segments.

6. Research, Development and Innovation (RD&I): Technological Knowledge Base (Patents) – General Trends and International Patent Holders

6.1. Overview of Semiconductor Patent Activity in Brazil

The examination of Brazil's semiconductor patent landscape provides crucial insights into the evolution of technological innovation in this strategic sector. Analysis of patent data from the National Institute of Industrial Property (INPI) reveals a sector characterized by significant foreign participation, cyclical growth patterns, and specialized areas of domestic strength.

From 1978 to 2024, Brazil has accumulated 17,176 semiconductor-related patents (**Figure 15**), with 13,482 (78%) filed at INPI by foreign assignees (see next subsection). This predominance of international patent holders underscores the global nature of semiconductor technology development and Brazil's position primarily as a technology recipient rather than an originator in this domain. However, domestic participation has shown meaningful improvement in recent periods.

Distribuition of semiconductor Patents by Year on Filing Brazil (INPI)

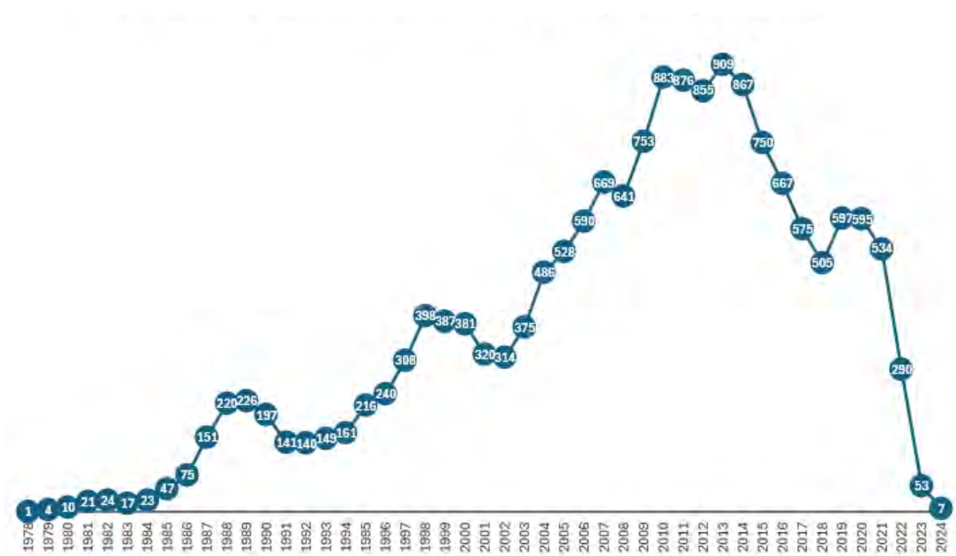

Figure 15. Total Semiconductor Patent Filed in the Brazilian Patent Office (INPI) per Year.

The historical trajectory of semiconductor patent activity in Brazil displays distinct phases of development. After modest activity through the mid-1980s, patent filings accelerated sharply from the 1990s through 2010, reaching peak volumes between 2009 and 2014. This period of expansion coincided with significant global developments in mobile communications, computing, and consumer electronics, as well as domestic policy initiatives discussed in Section 2, particularly the establishment of PADIS in 2007.

Since 2014, patent filings have shown a sustained decline, though the most recent years' data requires cautious interpretation due to the patent secrecy period and processing backlog at INPI. This pattern may reflect both global industry trends, including consolidation among semiconductor manufacturers, and domestic economic cycles. The sharp downward trajectory visible in the most recent data (2022-2024) likely represents administrative delays rather than an actual collapse in innovation activity.

Notably, Brazilian participation in semiconductor patents has risen from a historical average of 22% to 26% over the past 20 years (the effective patent validity window) and further to 34% in the last decade. This gradual increase suggests that policy initiatives such as PADIS may be contributing to a measured but meaningful boost in domestic innovation capacity.

6.2. Distribution of Patent Ownership: Foreign vs. Brazilian Assignees

The evolution of semiconductor patent ownership in Brazil reveals distinct trajectories for foreign and domestic assignees (**Figure 16**), reflecting broader economic and policy developments within the sector.

Semiconductor Patents by Origin of Assignee and Year of Filing in Brazil (INPI)

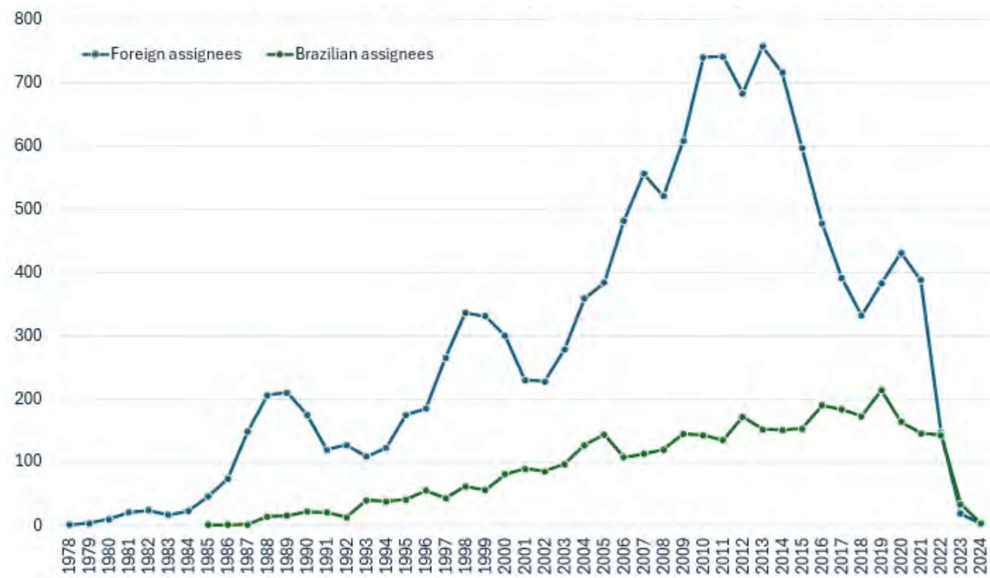

Figure 16. Semicondutor Patents by Origin of Assignee and Year of Filling in Brazil (INPI).

Foreign-owned filings demonstrate more pronounced cyclical patterns, with sharp growth periods followed by equally significant contractions. The trajectory shows three distinct eras: first cycle until the mid-1990s, accelerated growth through the early 2000s, and a dramatic surge peaking between 2010-2014, followed by a sustained decline. At their peak, foreign assignees filed more than 700 semiconductor patents annually in Brazil.

Several factors appear to have influenced these patterns:

- **Policy and economic drivers (1990s):** Trade liberalization, the anticipation of the Agreement on Trade-Related Aspects of Intellectual Property Rights (TRIPS), and Brazil's new intellectual property legislation (Law 9.279/96) likely stimulated foreign investment and patenting activity. This aligns with the semiconductor policy evolution, particularly the progression from the Information Technology Law of 1991 to more specialized frameworks.

- **Market opening and stabilization:** The removal of longstanding IT market reserves, implementation of the IT Law (1991), and post-hyperinflation economic reforms created favorable conditions for R&D investments by multinational corporations. These developments coincided with the initial surge in foreign patent filings.

- **Global technology cycles:** The peak filing period (2010-2014) corresponds to the worldwide smartphone revolution and expansion of mobile internet, driving innovation in specialized semiconductors for these applications.

In contrast, Brazilian assignees show a more gradual and sustained growth pattern from the early 2000s through approximately 2019. While domestic filings never approached the volume of foreign patents, their steadier trajectory suggests more consistent innovation capacity development, less subject to global industry cycles. This pattern likely reflects the influence of:

- **Post-2007 incentives:** The implementation of the Program to Support the Technological Development of the Semiconductor Industry (PADIS) appears to have supported the sustained growth of domestic filings during this period.

- **Development of the domestic innovation ecosystem:** The infrastructure developments and human capital initiatives, including the creation of CEITEC and expansion of academic research programs, have contributed to a more stable foundation for domestic patent generation.

Despite these positive developments, the volume disparity between foreign and Brazilian assignees remains substantial, reflecting continued technological dependence on global innovation centers.

6.3. Leading Patent Assignees in Brazil's Semiconductor Sector

Analysis of the top semiconductor patent holders in Brazil reveals a landscape dominated by multinational technology corporations, with limited representation from domestic entities (**Figure 17**)[2] .

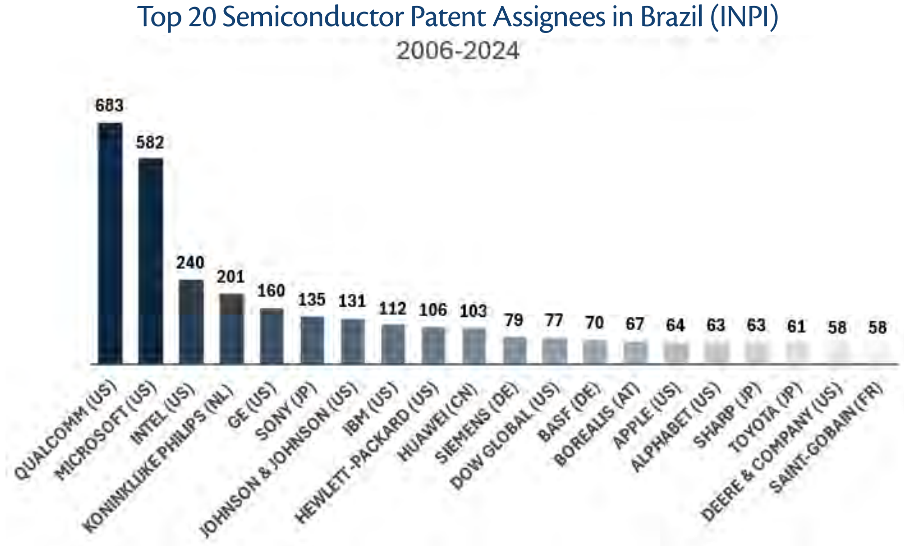

Figure 17. Significant Multinational Interest in Protecting Semiconductor Inventions in the Brazilian Market.

Qualcomm and Microsoft stand as the leading patent holders, with 683 and 582 patents, respectively, collectively accounting for approximately 10% of all semiconductor patents filed at INPI during the 2006-2024 period. This concentration at the top reflects both companies' strategic emphasis on semiconductor intellectual property for mobile communications and computing platforms. The

[2] In determining the leading patent holders, as shown in this and other figures, patents with multiple assignees were fully attributed to each assignee individually, rather than divided fractionally.

prominence of these firms confirms Brazil's position as a significant consumer market for mobile and computing products.

The top 10 assignees account for 20% of all semiconductor patents, while the top 20 represent 25%, indicating a relatively fragmented landscape beyond the leading companies. This pattern suggests that while global technology leaders maintain dominant positions, the broader semiconductor innovation ecosystem involves numerous specialized contributors.

The geographical distribution of the top 20 assignees demonstrates pronounced regional patterns:

- American companies dominate (11 of 20), reflecting the United States' traditional leadership in semiconductor design and systems applications.

- European firms hold significant positions (5 of 20), with particular strength in industrial and communications applications.

- Asian companies are represented (4 of 20), though their presence is less prominent than might be expected given the region's manufacturing dominance.

This distribution contrasts somewhat with the global semiconductor manufacturing landscape, where Asian firms (particularly from Taiwan, South Korea, and Japan) hold leading positions in fabrication. The patent data suggests that Brazil's semiconductor intellectual property environment primarily reflects design, systems, and applications innovation rather than core manufacturing processes, consistent with the value chain positioning described in Section 1 of this report.

Brazilian entities are notably absent from the top patent holders, indicating the challenges domestic firms face in building substantial semiconductor intellectual property portfolios. This absence reinforces previous observations regarding the nascent state of Brazil's semiconductor industry, with few active participants compared to the hundreds or thousands in countries where semiconductors represent a cornerstone industry.

6.4. Sectoral Distribution of Semiconductor Patents

The application domains of semiconductor patents filed in Brazil reveal distinct sectoral priorities and evolution patterns over time (**Figure 18**).

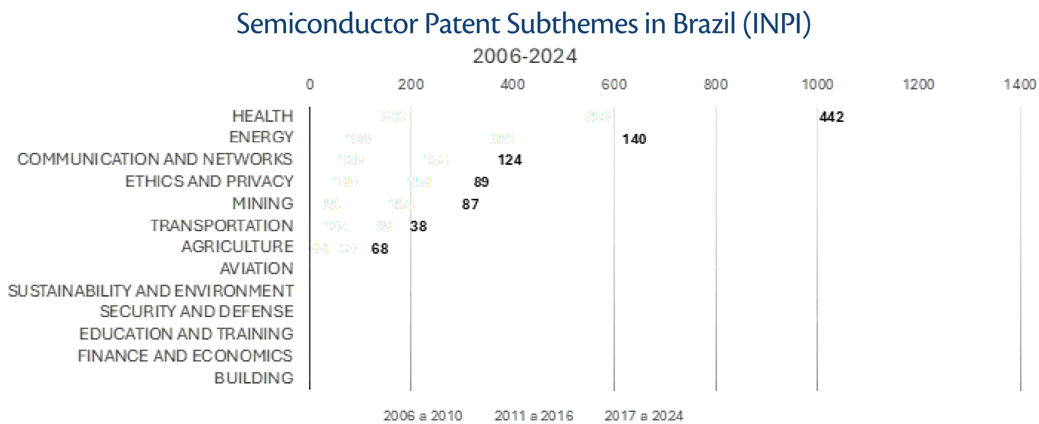

Figure 18. Semiconductor Patent Subthemes in Brazil (INPI).

Health applications represent the largest sector for semiconductor patents in Brazil (excluding functional applications and core semiconductor technologies, which account for approximately 50% of all patents). The prominence of health-related patents reflects both global trends in medical technology development and Brazil's strategic interests in healthcare innovation. The sustained growth in health-related semiconductor patents across all time periods (2006-2010, 2011-2016, and 2017-2024) demonstrates consistent investment in this application domain.

Energy applications constitute the second largest category, with particularly strong representation during the 2011-2016 period. This surge coincides with global developments in smart grid technologies, renewable energy systems, and power electronics, as well as Brazil's intensified exploration and production activities in its pre-salt oil reserves. The subsequent moderation in energy-related patents during 2017-2024 could reflect industry maturation rather than diminished interest as core technologies reached commercial deployment phases – yet, this insight must be confirmed once patent data for most recent years become available.

Communication and networks form the third major application domain, maintaining relatively consistent patent volumes across the analyzed periods. The stability suggests continuous innovation in this foundational sector despite technological evolution from 3G to 5G wireless standards.

Several secondary application domains demonstrate distinct temporal patterns:

- Ethics and privacy patents showed strong activity during 2006-2016 before declining, possibly reflecting the maturation of core data protection technologies.

- Mining applications peaked during 2011-2016, likely corresponding to the global commodities boom and subsequent slowdown.

- Transportation patents have declined progressively across periods, contrasting with global trends in automotive electrification.

Emerging application domains showing growth during the 2017-2024 period include agriculture and sustainability/environment. While still representing relatively small patent volumes, these sectors demonstrate an increasing interest in semiconductor applications for precision agriculture, environmental monitoring, and sustainable systems. The trend aligns with Brazil's strategic advantages in the agricultural sector and growing emphasis on environmental technologies.

The sectoral distribution patterns suggest that Brazil's semiconductor patent landscape increasingly reflects national priorities and competitive advantages rather than simply mirroring global technology trends. The growing emphasis on health, agriculture, and environmental applications highlights domains where Brazil possesses complementary strengths that can enhance the impact of semiconductor innovations.

6.5. Technical Focus Areas in Brazil's Semiconductor Patents

The technical content of semiconductor patents filed in Brazil spans a broad spectrum of technologies, from fundamental materials science to specific application domains (**Figure 19**).

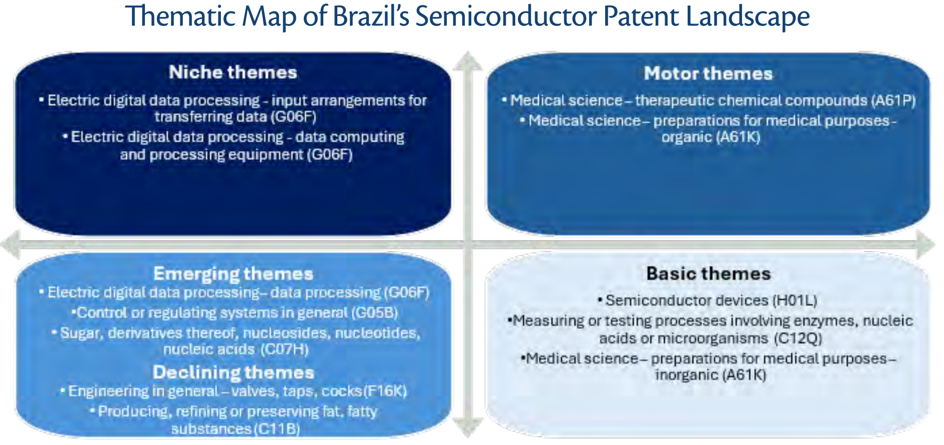

Figure 19. Thematic Map of Brazil's Semiconductor Patent Landscape.

Analysis of the semiconductor patent portfolio reveals four distinct categories of technical focus:

- **Basic themes** represent fundamental technologies with high centrality and widespread usage. These include core semiconductor devices (H01L classification), measuring or testing processes involving enzymes, nucleic acids or microorganisms (C12Q), and medical science preparations for medical purposes (A61K). These foundational technologies serve as enablers for more specialized applications and represent areas where established standards and platforms dominate.

- **Motor themes** combine high centrality with high density, indicating mature technologies with substantial development activity. In Brazil's context, these prominently include medical science applications, particularly therapeutic chemical compounds (A61P) and organic preparations for medical purposes (A61K). These areas align with the sectoral analysis in Section 6.4, confirming health applications as a central focus for semiconductor innovation in Brazil.

• **Niche themes** exhibit high density but lower centrality, representing specialized technical domains with intensive development. These include electric digital data processing focused on input arrangements for transferring data (G06F) and computing and processing equipment (G06F). Such niche areas likely reflect concentrated innovation by specific companies or research groups addressing particular market needs.

• **Emerging and declining themes** appear in the lower centrality and density quadrant, representing both nascent growth areas and fading technologies. The inference of which themes are emerging or declining often relies on expert knowledge, yet prospective growth patterns may suggest domains displaying genuine emergence:

o **Electric digital data processing (G06F)** demonstrates increasing relevance for digital transformation applications.

o **Control or regulating systems (G05B)** represents a growing focus area aligned with automation and Industry 4.0.

o **Biochemical compounds including nucleosides and nucleotides (C07H)** connects to expanding health-sector innovations.

Conversely, some technologies in this quadrant appear to be declining or stagnating:

o **Engineering in general – valves, taps, cocks (F16K)** represents more traditional applications with limited growth trajectory.

o **Fat and fatty substance processing (C11B)** shows minimal integration with advancing semiconductor technologies.

The mixed portfolio in this quadrant indicates Brazil's semiconductor landscape is simultaneously phasing out legacy applications while cultivating new interdisciplinary domains aligned with strategic priorities in digitalization, automation, and biotechnology.

The distribution across the four categories indicates a balanced innovation ecosystem that encompasses both established technologies and emerging domains. This technical diversity complements the sectoral distribution of the semiconductor technological base in Brazil and the research strengths previously identified, particularly in environmental technologies, materials science, and power electronics.

6.6. Strategic Positioning in Specialty Areas: Health and Energy

Examination of patent ownership in key application sectors reveals distinct competitive landscapes and opportunities for strategic positioning by Brazilian entities. In health-related semiconductor patents, the Johnson & Johnson group (including subsidiaries such as Ethicon) holds the dominant position with 118 patents, representing approximately 7% of all health-sector semiconductor patents in Brazil. This is followed by Koninklijke Philips (Netherlands) with 70 patents (4%). The distribution shows a pronounced concentration at the top, with a steep decline to subsequent assignees (**Figure 20**).

6.6.1. Health Sector

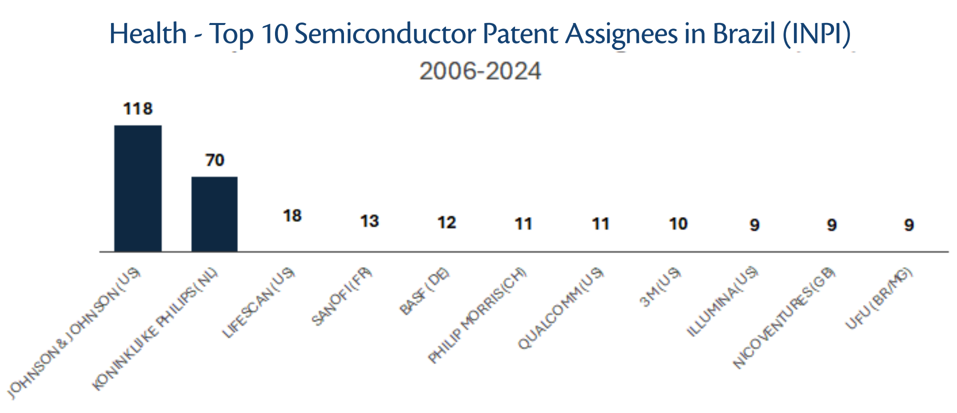

Figure 20. Top Holders of Health-related Semiconductor Patents in Brazil.

Notably, one Brazilian institution – Universidade Federal de Uberlândia (UFU) – appears tied for 8th position among top assignees for semiconductor patents in health from 2006 to 2024. While modest in absolute terms (9 patents), UFU's representation demonstrates the potential for domestic research institutions to establish specialized expertise in strategic application domains.

The health sector patent landscape is characterized by high fragmentation beyond the leading companies, with over 1,000 entities holding at least one health-related semiconductor patent in Brazil. Such a dispersed ownership structure suggests both the diversity of health applications for semiconductor technologies and potential opportunities for specialized innovation in Brazil.

6.6.2. Energy Sector

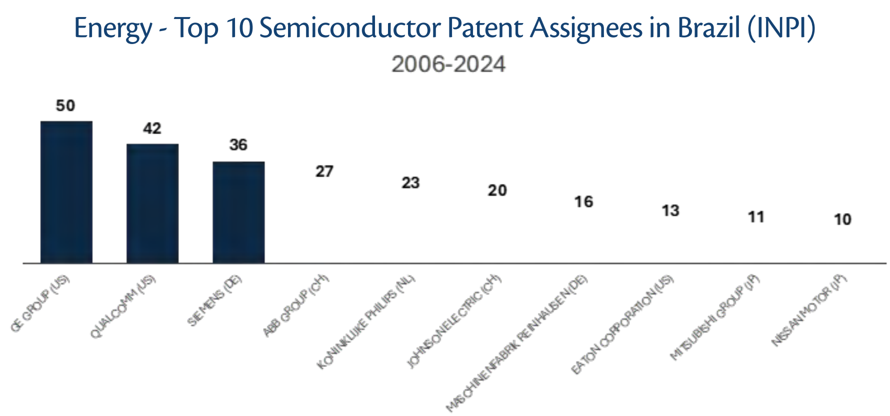

Figure 21. Top Holders of Energy - related Semiconductors Patents in Brazil

The significant presence of automotive and industrial companies among the top energy patent holders – including Mitsubishi Group, Nissan Motor, and ABB Group – highlights the increasing integration of semiconductor technologies into power systems, electric vehicles, and energy management applications.

Complementing this global trend, CEITEC, Brazil's National Center for Advanced Electronic Technology, emerges as the top Brazilian assignee in energy-related semiconductors, tied for 15th place among more than 500 patent holders in this domain. CEITEC's strong position reflects its strategic emphasis on energy applications, notably its shift toward silicon carbide semiconductors for clean energy technologies, aligning closely with Brazil's growing strengths in power electronics research.

The energy sector represents a particularly promising domain for increased Brazilian participation in semiconductor innovation, given both domestic research strengths and national priorities in renewable energy.

6.7. Concluding Remarks on Brazil's Semiconductor Patent Landscape

Brazil's semiconductor patent ecosystem reveals a complex innovation landscape characterized by significant foreign dominance, evolving research priorities, and emerging domestic capabilities in specialized domains. The analysis yields several key insights:

- **Foreign dominance with gradual domestic growth:** While foreign assignees account for 78% of all semiconductor patents filed in Brazil (1978-2024), Brazilian participation has risen from a historical average of 22% to 34% in the last decade, which suggests that policy initiatives such as PADIS have contributed to a measured but meaningful boost in domestic innovation capacity.

- **Concentration among global technology leaders:** Qualcomm and Microsoft collectively control 10% of all semiconductor patents filed since 2006, with the top 20 assignees representing 25% of the total. While such a concentration can be associated with the global industry structure, it may also indicate a fragmented landscape beyond leading companies, with opportunities for specialized innovation.

- **Sectoral diversification beyond computing:** While traditional computing applications remain important, sectoral distribution has expanded significantly into healthcare, energy, communications, and, more recently, agriculture and sustainability – a diversification trend that aligns with Brazil's strategic priorities and comparative advantages.

- **Technical breadth with specialized niches:** The technical focus spans from molecular compounds to systems applications, with emerging strengths in areas aligned with the research capabilities identified in Section 5, particularly in health, materials science, environmental technologies, and power electronics.

- **Institutional representation in strategic sectors:** Despite limited overall participation, Brazilian institutions have established footholds in specialized domains, with the Universidade Federal de Uberlândia (UFU) appearing among top health-sector patent holders and CEITEC emerging as a significant energy-sector assignee.

The patent landscape suggests that Brazil's most promising path forward lies not in competing directly with global giants across the full semiconductor spectrum but in strengthening domestic innovation capabilities in specialized segments that align with national priorities and research strengths. The gradual increase in Brazilian patent participation, particularly in strategically important sectors like health and energy, indicates that continued policy support and targeted investments in the innovation ecosystem can yield meaningful results.

7. Research, Development and Innovation (RD&I): Technological Knowledge Base (Patents) – International Patent Holders

7.1. Evolution of Brazilian Semiconductor Patent Activity

In contrast to the general patent landscape and trend in international assignees' activity, Brazil's domestic semiconductor patent activity demonstrates a distinctive trajectory characterized by gradual growth and increasing participation in the national innovation ecosystem. Analysis of data from the National Institute of Industrial Property (INPI) reveals that Brazilian assignees have steadily expanded their share of semiconductor patents from 18% in 2006 to 36% by 2019 (**Figure 22**), before the COVID-19 pandemic disrupted innovation activities globally.

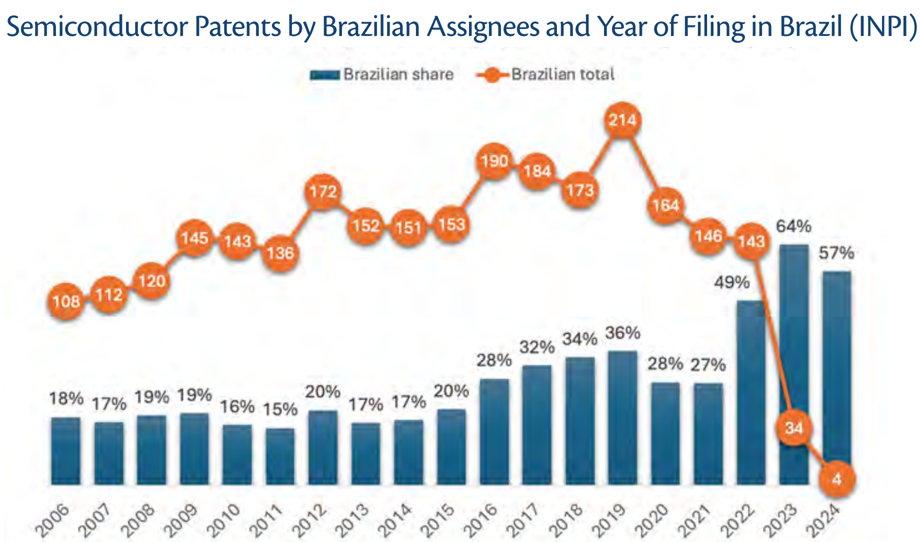

Figure 22. Semiconductor Patents by Brazilian Assignees and Year of Filing in Brazil (INPI).

This consistent growth in the proportional participation of Brazilian entities occurred despite overall declining patent volumes across the semiconductor sector after 2014 in Brazil. Notably, while foreign patent filings in Brazil experienced sharp cyclical patterns, Brazilian assignees maintained a more stable trajectory. The domestic patent activity displayed remarkable resilience particularly during the 2014-2019 period, when foreign filings were already contracting significantly. This pattern suggests that the implementation of targeted policies such as PADIS

(Program to Support the Technological Development of the Semiconductor Industry) in 2007 has contributed to a measured but meaningful boost in domestic innovation capacity.

The divergent trajectories of foreign and Brazilian assignees highlight an important development in Brazil's semiconductor innovation landscape. While international patent filings responded more directly to global industry cycles, Brazilian innovation activity – while still modest – appears to have developed greater autonomy, potentially reflecting the gradual maturation of domestic research capabilities and industrial applications. This interpretation aligns with the enhanced research ecosystem described in previous sections, where academic institutions have established specialized expertise in areas such as embedded systems, power electronics, and specific applications in health and energy domains.

7.2. Leading Brazilian Semiconductor Patent Assignees

The analysis of the top patent holders among Brazilian entities reveals a landscape dominated by academic institutions, with limited representation from industrial organizations **(Figure 23)**.

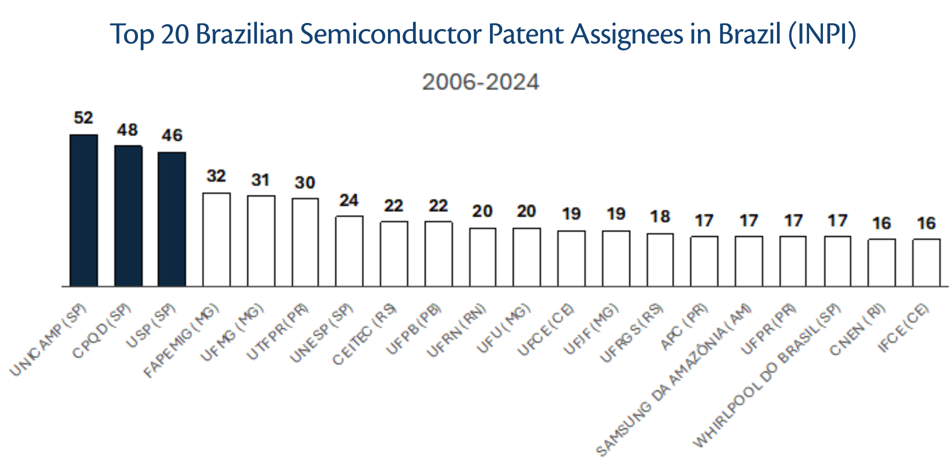

Figure 23. Top 20 Braizlian Semiconductor Patent Assignees in Brazil (INPI).

Between 2006 and 2024, the Brazilian semiconductor patent landscape was characterized by significant concentration among the leading academic institutions. The University of Campinas (UNICAMP) led with 52 patents, followed by the Centro de Pesquisa e Desenvolvimento em Telecomunicações (CPQD) – which has its roots in the Brazilian state-owned enterprise Telebras' R&D center and is also headquartered in Campinas – with 48 patents, and the University of São Paulo (USP) with 46 patents. Collectively, these three institutions account for approximately 7% of all Brazilian semiconductor patents filed during this period, a much lower concentration than the general picture presented in the previous section.

The dominance of academic institutions becomes even more pronounced when examining the top 20 patent assignees, with 17 of these positions occupied by universities and research centers. Only three non-academic entities appear among the top 20: two subsidiaries of multinational corporations (Samsung and Whirlpool) and one state-owned enterprise (CEITEC, the National Center for Advanced Electronic Technology).

The geographic distribution of leading academic assignees corresponds closely with the regional patterns of semiconductor research (Section 5), with institutions from São Paulo state (SP) collectively holding five positions among the top 20 assignees. This concentration reflects the state's established research infrastructure and significant investments in semiconductor-related sciences. Other states with substantial representation include Minas Gerais (MG), with four institutions, Paraná (PR), with three, and Rio Grande do Sul (RS), with two, reinforcing the South-Southeast regional concentration of semiconductor innovation capabilities in Brazil.

Notably, CEITEC appears in the 8th position among Brazilian assignees with 22 patents, confirming its significant role in the national semiconductor innovation landscape. Despite facing operational challenges that led to liquidation proceedings in 2020 (see Section 2), CEITEC established an important foundation for semiconductor intellectual property development in Brazil. Its position among the top domestic patent holders reinforces the strategic importance of its ongoing restructuring efforts, particularly its pivot toward silicon carbide semiconductors for clean energy applications.

The top 20 Brazilian assignees collectively account for 15% of all domestic semiconductor patents, with the remaining 85% distributed among over 2,000 entities. This highly fragmented landscape suggests both challenges and opportunities. While it indicates a diverse ecosystem with participation from many organizations, it also reflects the limited ability of most Brazilian entities to develop substantial patent portfolios that could provide competitive advantages in specific semiconductor application domains.

7.3. Sectoral Analysis of Brazilian Semiconductor Patents

The distribution of Brazilian semiconductor patents across application domains reveals both alignment with general patterns and distinctive national priorities (**Figure 24**).

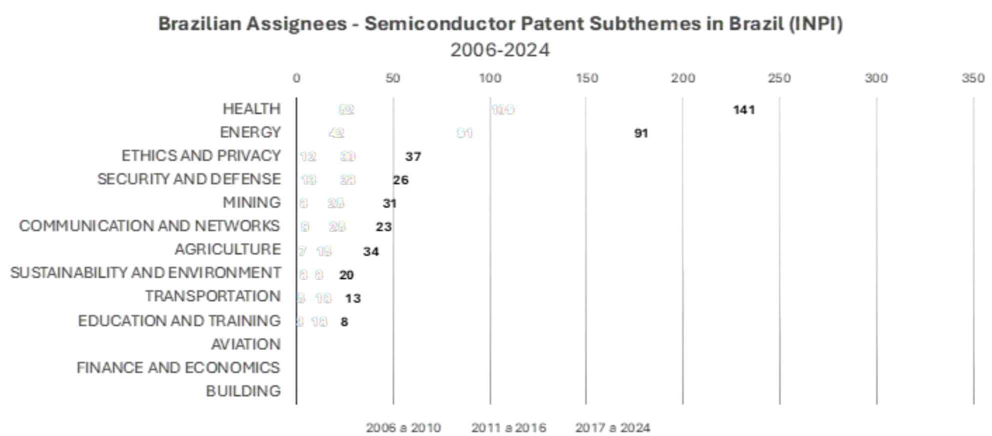

Figure 24. Semiconductor Patent Subthemes in Brazil (INPI).

Health applications represent the largest sectoral focus for Brazilian semiconductor patents, accounting for 11.4% of the total (excluding core semiconductor technologies and functional applications). This dominance mirrors the general pattern identified in Section 6, where health-related technologies also constituted the largest application domain. The sustained growth in health-related semiconductor patents throughout the analyzed periods (2006-2010, 2011-2016, and 2017-2024) demonstrates consistent investment in this strategic sector, aligning with Brazil's strong public health system and growing medical technology industry.

Energy applications form the second largest category, maintaining stable patent volumes across the three time periods. This consistent focus reflects Brazil's strategic interests in energy technologies, particularly related to the country's renewable energy matrix and smart grid developments, but also continued exploration of deep-sea oil reserves. The stability in energy-related patenting contrasts with the surge and subsequent moderation observed in foreign assignee patents within this domain.

Several notable differences emerge when comparing Brazilian sectoral patterns with the overall distribution dominated by foreign assignees. Brazilian patents show a lower emphasis on communications and networks, reflecting a possibly limited domestic capacity in telecommunications equipment manufacturing. Conversely, Brazilian assignees demonstrate a higher focus on security and defense applications, potentially indicating alignment with national strategic priorities in these domains.

Ethics and privacy applications rank third among Brazilian patents, higher than their positioning in the overall landscape. This increased focus may reflect growing concerns about data protection and privacy considerations in technological development, particularly in relation to Brazil's implementation of the General Data Protection Law (LGPD – Law No. 13,709/2018) in recent years.

Emerging areas showing growth in the 2017-2024 period include mining, agriculture, and sustainability and environment. The increasing attention to agricultural applications (albeit small in absolute numbers: 56 patents across the full period) aligns with Brazil's position as an agricultural powerhouse and suggests a growing integration of semiconductor technologies in precision farming, automation, and monitoring systems. Similarly, the growth in sustainability and environmental applications indicates rising awareness of semiconductor contributions to addressing environmental challenges, potentially including monitoring systems, resource optimization technologies, and clean energy applications.

The sectoral evolution across time periods reveals a progressive diversification of Brazilian semiconductor innovation. While traditional categories like health and energy maintain their leadership, the emergence and growth of specialized domains reflect both global technological trends and distinctive national priorities shaped by Brazil's economic structure and development objectives.

7.4. Technical Focus Areas of Brazilian Semiconductor Patents

The technical content of semiconductor patents filed by Brazilian assignees spans diverse technological domains, creating a complex innovation landscape with distinct areas of specialization (**Figure 25**).

Thematic Map of Brazil's Semiconductor Patent Landscape (Domestic Assignees)

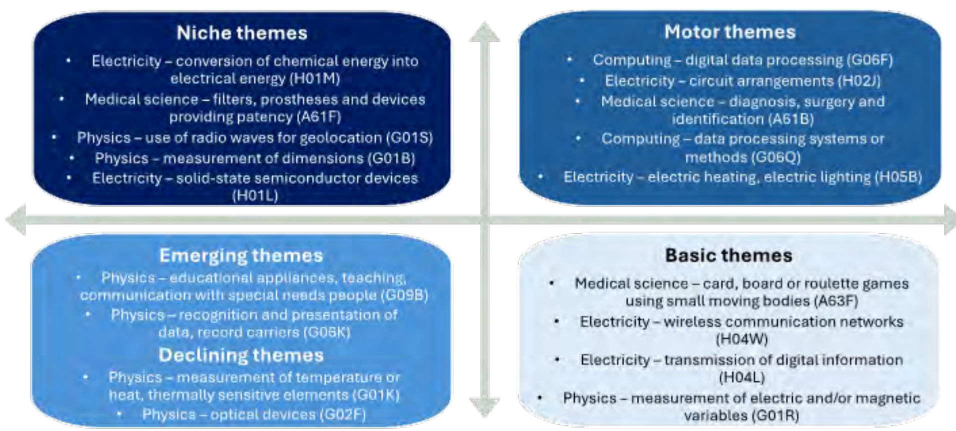

Figure 25. Technological Map of National Semiconductor Patents.

Analysis of patent classifications reveals four distinct categories of technical focus among Brazilian semiconductor patents:

• **Motor themes** represent mature technologies with high centrality and density, indicating substantial development activity in well-established domains. For Brazilian assignees, these prominently include computing technologies focused on digital data processing (G06F), electrical technologies related to circuit arrangements (H02J), and medical science applications for diagnosis, surgery, and identification (A61B). These areas form the core of Brazil's semiconductor innovation capabilities, demonstrating concentrated expertise in computing infrastructure, power management systems, and medical devices.

• **Basic themes** show high centrality but lower density, representing fundamental technologies with widespread usage but less intensive innovation. In the Brazilian context, these include wireless communication networks (H04W), digital information transmission (H04L), and measurement of electrical variables (G01R). The presence of these foundational technologies indicates Brazil's engagement with essential semiconductor applications, though perhaps with less concentrated innovation activity than in motor or niche themes.

• **Niche themes** exhibit high density but more limited centrality, representing specialized technical domains with intensive development in focused areas. Brazilian strengths in this category include technologies for converting chemical energy into electrical energy (H01M), medical devices such as filters and prostheses (A61F), and various physics-based applications including radio wave geolocation (G01S) and dimensional measurement (G01B). These niche areas may represent opportunities for Brazilian entities to develop distinctive competencies in specialized markets with limited global competition.

• **Emerging and declining themes** with lower centrality and density represent both nascent growth areas and fading technologies. Among these, emerging technologies showing promise include educational appliances (G09B), alongside digital education trends, data recognition and record carriers (G06K) supporting IoT applications, and optical devices (G02F) for advanced photonics. Conversely, possible declining themes likely include technologies related to traditional mechanics and engineering elements like valves and taps (F16K) and fat processing (C11B) that show minimal integration with advancing semiconductor technologies. This mixed portfolio indicates Brazil's semiconductor landscape is simultaneously developing new interdisciplinary capabilities while phasing out legacy applications.

This technical distribution complements the sectoral analysis by illuminating the specific capabilities underlying Brazil's semiconductor innovation. The strong presence of medical and computing technologies aligns with the sectoral focus on health applications, while electrical energy conversion technologies support the emphasis on energy applications.

The technical profile differs somewhat from the international patent landscape analyzed in Section 6. While both domestic and foreign assignees demonstrate an interest in healthcare technologies, Brazilian entities show distinctive strengths in educational applications and measurement technologies that may reflect specialized institutional expertise or alignment with national priorities in education and infrastructure development.

7.5. Strategic Positioning in Specialty Areas: Health and Energy

Examining patent ownership in key application sectors reveals distinctive competitive landscapes and specialized focus areas among Brazilian assignees.

7.5.1. Health Sector

The health sector represents the most prominent application domain for Brazilian semiconductor patents, with a distinctive ecosystem dominated by academic institutions (**Figure 26**).

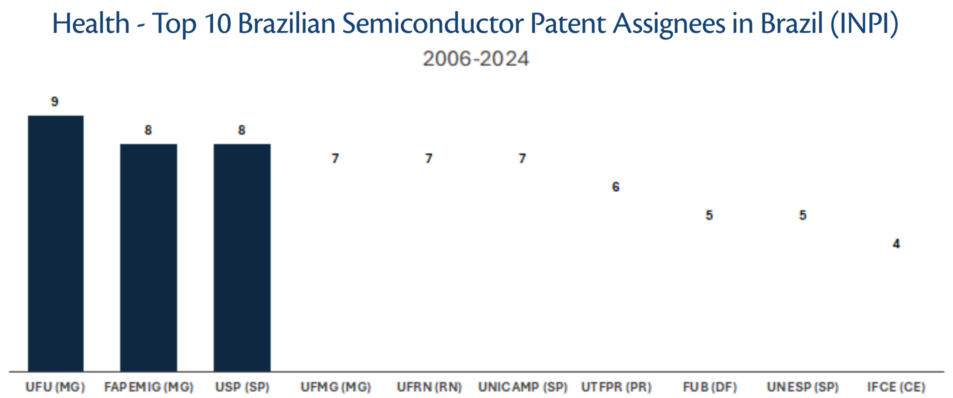

Figure 26. Health - Top 10 Brazilian Semiconductor Patent Assignees in Brazil (INPI).

The Federal University of Uberlândia (UFU) leads Brazilian semiconductor patent assignees in the health sector with 9 patents, followed by the Minas Gerais State Research Foundation (FAPEMIG) and the University of São Paulo (USP) with 8 patents each. The dominance of academic institutions is particularly pronounced in this domain, with all top 10 positions occupied by universities or research foundations, predominantly from the Southeast region (Minas Gerais and São Paulo states).

This pattern contrasts sharply with the health sector patent landscape for all assignees described in Section 6, where multinational corporations like Johnson & Johnson and Philips held leading positions. The absence of Brazilian companies among top health-sector assignees suggests limited industrial application of semiconductor innovations in healthcare, despite the substantial academic research activity. The effective conversion of scientific and technological knowledge into commercial innovations represents a significant challenge for Brazil's semiconductor ecosystem, highlighting the need for strengthened university-industry partnerships, targeted technology transfer mechanisms, and policy instruments that facilitate the transition from research outcomes to market-ready products in strategic health applications.

The top 10 Brazilian assignees collectively account for 17% of health-related semiconductor patents by domestic entities, indicating a moderate concentration of intellectual property in this domain. This concentration may create opportunities for enhanced knowledge transfer and commercialization through targeted programs linking academic research with industrial applications.

Notably, UFU's leading position in health-related semiconductor patents reinforces the observation regarding its emerging specialization in this domain. As one of the few Brazilian institutions appearing among top patent holders in health generally, UFU demonstrates the potential for domestic research organizations to establish specialized expertise in strategic application domains.

7.5.2. Energy Sector

The energy sector presents a more balanced distribution of patent ownership between academic and industrial entities, suggesting greater integration between research and commercial applications (**Figure 27**).

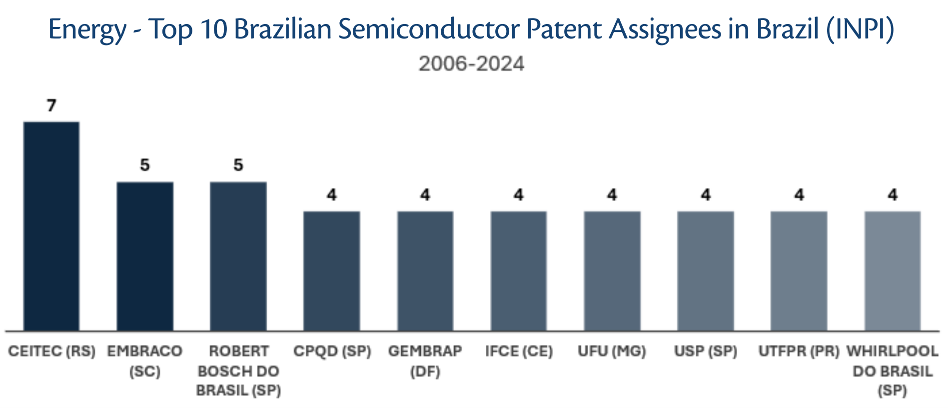

Figure 27. Energy - Top 10 Brazilian Semiconductor Patent Assignees in Brazil (INPI).

CEITEC leads Brazilian semiconductor patent assignees in the energy sector with 7 patents – as already stated, CEITEC's portfolio reinforces its strategic positioning in energy applications. Its leadership in this domain aligns with its recent restructuring toward silicon carbide semiconductors for clean energy applications, suggesting that the organization had established relevant technological capabilities even before this strategic pivot.

Unlike the health sector, the energy domain features significant participation from industrial entities. Embraco (a compressor manufacturer, previously part of Whirlpool's Brazilian subsidiary) and Robert Bosch do Brasil hold the second and third positions with 5 patents each, while Whirlpool do Brasil appears in the tenth position with 4 patents. This industrial presence indicates greater maturity in translating semiconductor innovations into commercial energy applications.

The diverse composition of top energy-sector assignees – including a state-owned enterprise (CEITEC), large multinational subsidiaries (Bosch, Whirlpool), a medium-sized enterprise (GEMBRAP), and several academic institutions – suggests a more integrated innovation ecosystem for energy applications. This balanced distribution between academic and industrial patent holders is yet another structure to facilitate knowledge transfer and technological development in this strategic sector.

Compared with the energy sector patent landscape for all assignees, Brazilian entities occupy specific niches rather than competing directly with global leaders like GE Group, Qualcomm, and Siemens. CEITEC's leading position among Brazilian assignees (and tied for 15th place overall) demonstrates the potential for domestic organizations to establish meaningful intellectual property portfolios in this domain.

7.6. Concluding Remarks on Brazil's Domestic Semiconductor Patent Landscape

Brazil's domestic semiconductor patent landscape reveals a resilient innovation ecosystem evolving against the backdrop of global industry cycles. Despite relatively modest volumes compared to international filings, Brazilian patent activity has charted a counterintuitive path, continuing to grow rather than declining after 2014. This resilience suggests that policy interventions such as PADIS have contributed to fostering local innovation capabilities that operate with some independence from global industry trends.

Several distinctive characteristics define Brazil's semiconductor patent ecosystem:

- First, academic dominance represents both strength and challenge. Universities and research institutions hold most of the leading positions among Brazilian assignees, demonstrating strong fundamental research capabilities but suggesting limited industrial application. The preponderance of academic patents indicates potential commercialization challenges that might require targeted policies to bridge the gap between research and market applications.

- Second, strategic sectoral focus on health and energy applications aligns with both global trends and national priorities. The sustained emphasis on these domains, coupled with emerging interest in areas such as agriculture, mining, and environmental technologies, suggests an increasingly diverse innovation portfolio responding to distinctive national needs and opportunities.

- Third, complementary technical strengths in computing, medical devices, and electricity management support application-focused innovation rather than fundamental semiconductor manufacturing processes. This technical profile reflects Brazil's positioning in the semiconductor value chain earlier, with greater emphasis on design, integration, and specialized applications rather than front-end fabrication.

- Fourth, the highly fragmented ownership landscape, with top 20 assignees representing only 15% of domestic patents distributed among over 2,000 entities, indicates both challenges in building substantial intellectual property portfolios and opportunities for specialized innovation in targeted niches.

The evolution of Brazil's domestic semiconductor patent landscape complements the international patent analysis in Section 6 by highlighting distinctive national capabilities and trajectories. Despite significant foreign dominance in absolute patent numbers, Brazilian entities have steadily increased their proportional participation and established specialized expertise in strategic domains. This gradual progress suggests that continued policy support and targeted investments in the innovation ecosystem can yield meaningful results in strengthening Brazil's position in the global semiconductor landscape.

8. Conclusion: Brazil's Semiconductor Innovation Ecosystem - Strategic Positioning and Future Directions

8.1. The Current State of Brazil's Semiconductor Landscape

Brazil's semiconductor landscape presents a complex picture that reflects significant achievements from developments in the past 35 years, while persistent challenges remain. The analysis of policies, investments, and research and development activities across previous sections reveals a country striving to establish technological sovereignty in this strategic sector while adapting to the local context of dependency and global industry realities.

The SWOT analysis of Brazil's semiconductor ecosystem highlights notable strengths (Figure 28). Brazil has developed a robust university-led semiconductor research ecosystem, with institutions such as USP, UNICAMP, UFRGS, and UFMG forming its backbone. This academic foundation has established Brazil as a regional leader in semiconductor research output, with a growing global research contribution that reached nearly 2% of global semiconductor research output by 2020-2021. The country has demonstrated distinctive expertise in specialized applications, including photocatalysis, environmental technologies, and materials science, creating potential niches for competitive development.

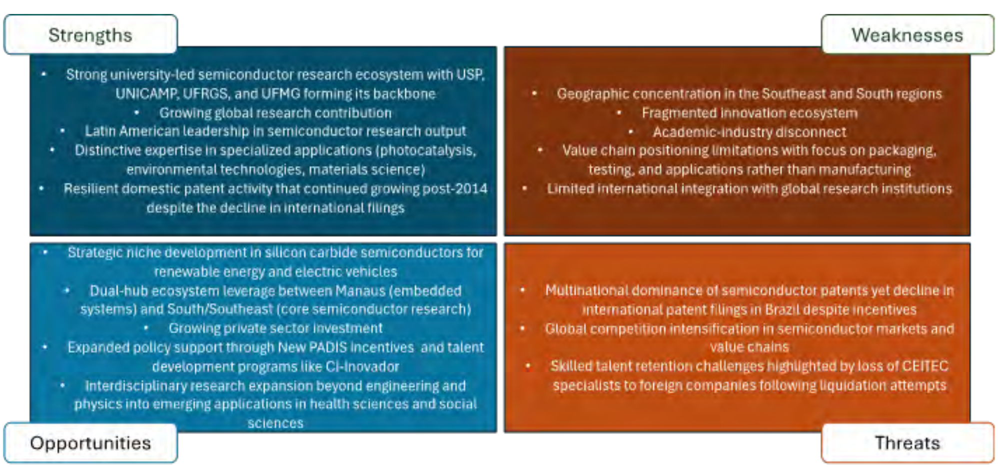

Figure 28. Brazil's Semiconductor Landscape: SWOT Analysis.

One of the most promising indicators of Brazil's strategic development is the resilience of domestic patent activity. Brazilian assignees have steadily expanded their share of semiconductor patents from 18% in 2006 to 36% by 2019. This growth continued even after 2014, when international patent filings began to decline, suggesting that policy initiatives such as PADIS may have successfully stimulated domestic innovation capabilities with some degree of independence from global industry cycles.

However, significant weaknesses persist that limit the potential of Brazil's semiconductor ecosystem. The geographic concentration of research and innovation activities in the Southeast and South regions creates regional imbalances that may restrict national development. The fragmented innovation ecosystem, with limited connection between academic research and industrial applications, represents perhaps the most significant structural challenge. Consequently, an academic-industry disconnect may indicate limited industrial conversion of university-generated semiconductor patents. The health sector, in particular, appears to illustrate this dynamic, given the predominance of academic institutions among patent holders.

Value chain positioning also presents limitations, with Brazil's activities primarily focused on back-end operations such as packaging, testing, and applications rather than front-end manufacturing. While this positioning reflects realistic adaptation to global competition, it also reinforces technological dependencies that may limit longer-term development. Similarly, the limited international integration with global research centers, despite growing collaboration, constrains Brazil's access to advanced technological knowledge and infrastructure.

External threats further complicate Brazil's semiconductor development trajectory. Section 6 highlighted the multinational dominance of semiconductor patents in Brazil, with foreign assignees accounting for 74% of all semiconductor patents filed between 2006 and 2024. The significant decline in international patent filings since 2014, despite continued incentives through PADIS, raises questions about whether Brazil's current policies provide sufficient motivation for global innovation leaders to establish local semiconductor R&D operations. Additionally, the intensification of global competition in semiconductor markets and value chains presents challenges for establishing distinctive national capabilities.

8.2. Comparison Between Multinational and Brazilian Semiconductor Innovation

Talent retention represents another critical concern. The liquidation proceedings for CEITEC in 2020 resulted in the loss of highly qualified designers to international companies, highlighting the vulnerability of Brazil's specialized semiconductor workforce to global mobility and competitive pressures.

Table 2. Comparison between Multinational Corporations and Brazilian Institutions in Semiconductor Patent Activity

	Multinational Corporations	Brazilian Institutions
Patent volume	74% of semiconductor patents filed in Brazil in 2006-2024	26% of semiconductor patents filed in Brazil in 2006-2024
Growth trends	Significant decline since 2014 peak despite PADIS incentives	Steady growth since 1990s, accelerating after PADIS (2007) with peak in 2019
Top patent holders	Qualcomm and Microsoft account for 10% of all patents	Highly fragmented – top 20 Brazilian assignees hold only 15% of domestic patents
Institutional types	Global technology corporations dominate (Qualcomm, Microsoft, Intel, Philips)	Universities and research institutions dominate; only one national enterprise (CEITEC) among top 20 patent holders
Focus areas	Health, Energy, and Communications & Networks	Health, Energy, and Ethics & Privacy
Emerging specialization	Agriculture and Sustainability & Environment	Mining, Agriculture and Sustainability & Environment
Geographical pattern	Global R&D with protection in Brazilian market, local R&D by subsidiaries	Concentrated in South/Southeast with distinct hub in Manaus (Amazonas)
Technology maturity	Advanced commercial applications with global integration	Basic computing technologies with niche applications in emerging fields
Strategic priorities	Market protection in growing Brazilian economy	University research excellence with limited commercialization pathways
Collaboration model	Limited engagement with Brazilian innovation ecosystem (low co-patenting activity)	University-centered with higher co-patenting activity (often with enterprises)

Foreign assignees dominate the semiconductor patent landscape in Brazil, accounting for 74% of all semiconductor patents filed between 2006 and 2024. This dominance reflects both the global nature of semiconductor technology development and Brazil's position primarily as a technology recipient rather than an originator in this domain. The analysis in Section 6 showed that Qualcomm and Microsoft stand as the leading patent holders, with 683 and 582 patents, respectively, collectively accounting for approximately 10% of all semiconductor patents filed at INPI during this period.

However, while MNC patent activity has significantly declined since its 2014 peak despite PADIS incentives, Brazilian semiconductor innovation has demonstrated remarkable resilience. As documented in Section 7, domestic technological development has shown steady growth since the 1990s, with acceleration after PADIS implementation in 2007 and a peak in 2019. The contrasting trajectory suggests that Brazil's domestic innovation ecosystem has developed a degree of autonomy from global industry cycles, potentially reflecting the maturation of national research capabilities and the effectiveness of targeted policy support.

The institutional composition of patent holders also differs significantly between multinational and Brazilian assignees. Global technology corporations dominate the multinational landscape, with companies like Qualcomm, Microsoft, Intel, and Philips holding substantial patent portfolios. In contrast, the Brazilian patent landscape is dominated by universities and research institutions, with 17 of the top 20 positions occupied by academic entities. Only three non-academic organizations appear among the top 20 Brazilian assignees: two subsidiaries of multinational corporations (Samsung and Whirlpool) and one state-owned enterprise (CEITEC).

The academic dominance in Brazilian patent activity reflects both a strength in fundamental research capabilities and a structural challenge in translating scientific knowledge into commercial applications. The preponderance of academic patents indicates potential commercialization challenges that might require targeted policies to bridge the gap between research and market applications.

The sectoral focus also reveals interesting distinctions. Both multinational and Brazilian assignees prioritize health and energy applications but with different secondary emphases. Multinational corporations show greater activity in communications and networks, while

Brazilian institutions demonstrate higher interest in ethics and privacy applications, potentially reflecting growing national concerns about data protection following the implementation of the General Data Protection Law (LGPD) in 2018.

Geographic patterns further differentiate the two groups. Multinational corporations typically approach the Brazilian market as part of their global market positioning strategy, with limited integration into the local innovation ecosystem. In contrast, Brazilian innovation shows a distinctive regional concentration in the South/Southeast with a specialized hub in Manaus (Amazonas), as mapped in Section 4. The Brazilian dual-hub structure creates complementary capabilities, with academic research centers in the South/Southeast and industrial applications concentrated in Manaus, leveraging the Manaus Free Trade Zone's infrastructure and incentives.

The technological maturity also differs substantially. Multinational patents typically represent advanced commercial applications with global integration, while Brazilian innovations tend to focus on basic computing technologies with emerging applications in specialized fields. Brazilian agents, therefore, seem to be positioning themselves in the semiconductor value chain with greater emphasis on implementation and integration rather than fundamental manufacturing processes.

8.3. A Framework for Advancing Brazil's Semiconductor Strategy Through Collaboration

Based on the comprehensive analysis of Brazil's semiconductor landscape, a strategic framework emerges that could guide future development through enhanced collaboration across institutional sectors and geographic regions.

8.3.1. Strategic Positioning

The first dimension of this framework addresses Brazil's strategic positioning within the global semiconductor value chain. Brazil has strategically positioned itself in segments that align with its existing industrial capabilities and technological expertise. Rather than attempting to compete in capital-intensive front-end manufacturing, Brazil could leverage its established strengths in semiconductor applications, implementation, and integration.

Such an approach acknowledges the global realities of semiconductor manufacturing, which has become increasingly concentrated, capital-intensive, and technologically specialized. By focusing on strategic niches where Brazil has demonstrated research strength – including health applications, renewable energy technologies, silicon carbide semiconductors, and environmental technologies – the country can develop distinctive competencies that complement rather than directly compete with established global capabilities.

The revitalization of CEITEC exemplifies this strategic positioning with its pivot toward silicon carbide semiconductors for clean energy applications. The R$220 million investment planned for 2024-2026 aligns with global trends toward high-performance power electronics for decarbonization processes, positioning Brazil in a growing segment with significant future potential.

Building upon existing regional strengths represents another key element of strategic positioning. The dual-hub ecosystem, with South/Southeast academic research centers and Manaus industrial applications clusters, creates natural foundations for specialized development. Strengthening connections between these complementary capabilities could enhance both fundamental research and commercial applications.

8.3.2. Institutional Coordination

The second dimension focuses on institutional coordination to address what previous sections identified as perhaps the most significant structural challenge: the disconnect between academic research and industrial applications.

Bridging this academic-industrial divide requires establishing formal pathways between university research centers and industrial applications. The absence of Brazilian companies among top health-sector patent assignees, despite substantial academic research activity, illustrates the need for strengthened university-industry partnerships and targeted technology transfer mechanisms.

Creating specialized collaborative centers that connect PADIS tax incentive recipients with patent-producing universities represents a potential mechanism for enhancing knowledge flow. Such centers could focus on specific application domains where Brazil has demonstrated research strengths, such as health technologies, energy systems, and environmental applications.

Structuring technology transfer offices specifically focused on semiconductor applications could accelerate the commercialization of academic research. The Embrapii (Brazilian Company for Research and Industrial Innovation) centers present an excellent existing mechanism for this purpose, as they already operate with a collaborative funding model that joins public resources with private investments to support applied research and innovation between academic institutions and industry. Additionally, selected Núcleos de Inovação Tecnológica (NITs, meaning "Technological Innovation Centers"), which are university-connected entities established by the Brazilian Innovation Law (No. 10,973/2004) to manage intellectual property and facilitate collaboration between academia and industry, could be adapted and specialized specifically for semiconductor applications. The geographic concentration of research in institutions like USP, UNICAMP, UFRGS, and UFMG suggests that targeted investments in technology transfer capabilities at these leading institutions could yield significant returns.

Formalizing partnerships with active multinational corporations in Brazil represents another institutional coordination mechanism. Despite declining international patent filings since 2014, selective engagement with multinational corporations whose technological focus aligns with Brazil's strategic priorities could create mutually beneficial collaborations. The emerging photovoltaic sector emphasized in the new PADIS offers one such opportunity for strategic partnership.

8.3.3. Capacity Development

The third dimension addresses human capital development, which previous sections identified as essential for sustaining innovation capabilities in the semiconductor sector. Expanding CI-Inovador training initiatives, with a targeted focus on semiconductor design, packaging, and testing would address the industry's practical workforce needs. The program's monthly scholarships and international exposure represent valuable mechanisms for developing specialized expertise aligned with Brazil's strategic positioning in the semiconductor value chain.

Implementing joint academic-industry PhD programs focused on Brazil's strategic application domains in semiconductors could strengthen connections between research and commercial development. Such programs could build upon the established research strengths at the leading institutions – but also at other institutions outside the South/Southeast regions to promote regional diversification –while incorporating practical industry challenges to enhance relevance and application potential.

Establishing international exchange programs with semiconductor manufacturing hubs would provide valuable knowledge transfer while focusing on Brazil's complementary strengths rather than attempting to replicate existing global capabilities. This approach acknowledges Brazil's position in the semiconductor value chain while seeking to enhance capabilities in strategic niches.

Expanding Brazil's international research collaboration networks, which are already growing with approximately 40% of Brazilian papers co-authored internationally, would strengthen the university-led ecosystem while maintaining Brazil's Latin American leadership position. Strategic collaborations with global research centers in areas of mutual interest could accelerate knowledge development and application in specialized domains.

8.4. Connecting Policy, Investment, and Outcomes in Brazil's Semiconductor Ecosystem: Cross-Cutting Themes

The comprehensive analysis of Brazil's semiconductor landscape reveals interconnected relationships between policy evolution, strategic investments, and research, development, and innovation outcomes. Several cross-cutting themes emerge from the analysis, shaping Brazil's semiconductor ecosystem across policy, investment, and innovation dimensions:

• Regional Concentration: The South/Southeast academic hub and Manaus industry cluster create a geographic specialization that both enables focused development and potentially limits national integration. This concentration reflects historical patterns of industrial and academic development but may restrict the broader distribution of semiconductor capabilities throughout Brazil.

• Value Chain Positioning: Brazil's focus on applications, implementation, and integration rather than front-end manufacturing represents a strategic adaptation to global industry realities. This approach acknowledges the capital-intensive and technologically specialized nature of semiconductor manufacturing while leveraging Brazil's existing industrial capabilities and technological expertise.

• Strategic Application Focus: The emphasis on health, energy, agriculture, and environmental sustainability applications aligns with Brazil's national priorities and comparative advantages. This focus creates opportunities for distinctive development in sectors where Brazil has established strengths or strategic interests.

• Academic-Industrial Collaboration Challenge: The disconnect between university-led research and industrial applications represents perhaps the most significant structural challenge for Brazil's semiconductor ecosystem. The preponderance of academic patents indicates potential commercialization challenges that might require targeted policies to bridge the gap between research and market applications.

8.5. Recommendations

Brazil's semiconductor landscape presents a complex picture of progress and challenges, characterized by strategic policy development, significant investments, and growing research and innovation capabilities. The country has established a foundation for semiconductor development that leverages existing strengths while adapting to global industry realities.

The comprehensive analysis of Brazil's semiconductor ecosystem points to several strategic recommendations that could strengthen the country's position in this critical technological domain:

8.5.1. Strategic Niche Development and Value Chain Positioning

Rather than competing directly with global leaders across the full semiconductor spectrum, Brazil should focus on strengthening domestic innovation capabilities in specialized segments that align with national priorities and established research strengths. The strategic pivot of CEITEC toward silicon carbide semiconductors for clean energy applications exemplifies this approach. Additional investment in strategic niches where Brazil has demonstrated research excellence – such as photocatalysis, environmental monitoring technologies, and health applications – would leverage existing capabilities while developing distinctive competencies in growing global markets.

This approach acknowledges Brazil's position in the semiconductor value chain, focusing on applications, testing, and system integration rather than capital-intensive front-end manufacturing. Investing in specialized testing and integration infrastructure would support this positioning while enhancing domestic capabilities in strategic applications.

8.5.2. Bridging the Academic-Industrial Divide

The disconnect between university-led research and industrial applications represents the most significant structural challenge for Brazil's semiconductor ecosystem. Addressing this gap requires coordinated action through multiple mechanisms:

- Establishing targeted funding programs that explicitly connect universities with semiconductor manufacturers, enabling research-driven innovation in Brazil's specialized application domains.

• Leveraging Embrapii centers as platforms for collaborative semiconductor innovation, building on their established model of joint public-private funding.

• Developing specialized technology transfer offices at leading research institutions like USP, UNICAMP, UFRGS, and UFMG that focus specifically on semiconductor applications.

• Creating collaborative innovation centers in strategic locations that connect PADIS tax incentive recipients with patent-producing universities.

These initiatives would help translate Brazil's substantial academic research output into commercial applications, addressing the imbalance observed in the patent landscape where universities dominate domestic semiconductor innovation with limited industrial conversion.

8.5.3. Human Capital Development and Retention

Sustaining innovation capabilities requires focused attention on developing and retaining specialized talent. The loss of CEITEC specialists to foreign companies following liquidation attempts highlights this vulnerability. Strengthening human capital development through coordinated initiatives would enhance Brazil's long-term competitiveness:

• Expanding and targeting CI-Inovador training initiatives to focus on semiconductor design, packaging, and testing.

• Implementing joint academic-industry PhD programs focused on Brazil's strategic application domains.

• Establishing international exchange programs with semiconductor manufacturing hubs while focusing on Brazil's complementary strengths.

- Creating career pathways and incentives for semiconductor specialists that encourage retention within Brazil's innovation ecosystem.

These human capital initiatives would address both immediate workforce needs and long-term innovation capabilities, creating a sustainable foundation for Brazil's semiconductor development.

8.5.4. Enhanced International Collaboration

While Brazil has established a position as Latin America's leader in semiconductor research, strengthening international connections would accelerate knowledge development and application:

- Formalizing strategic partnerships with multinational corporations operating in Brazil, focusing on technology transfer and collaborative innovation.

- Expanding research collaboration networks with global centers of semiconductor excellence in areas of mutual interest.

- Developing South-South cooperation, particularly within Latin America, where Brazil's leadership position creates natural opportunities for regional innovation networks.

- Engaging with international semiconductor initiatives while maintaining focus on Brazil's strategic niches and comparative advantages.

These international connections would enhance Brazil's access to global knowledge networks while strengthening its distinctive contributions to semiconductor innovation.

8.6. Final Considerations

The time to act is now. Brazil has developed significant scientific and technological foundations through decades of policy support and institutional development. However, translating these foundations into industrial competitiveness and technological sovereignty requires deliberate action to address structural challenges, particularly the gap between research excellence and commercial application.

By implementing these integrated recommendations, Brazil can position itself strategically in the global semiconductor ecosystem, developing distinctive capabilities that enhance both economic competitiveness and technological independence. Success will depend on maintaining policy consistency, ensuring coordination between public and private stakeholders, and focusing resources on areas of strategic priority where Brazil can establish and sustain competitive advantages.

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