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ITAIPU BINACIONAL: INOVAÇÃO E DESENVOLVIMENTO REGIONAL INTEGRADOS ALÉM DA GERAÇÃO DE ENERGIA SUSTENTÁVEL

ITAIPU BINACIONAL: INTEGRATING INNOVATION, REGIONAL DEVELOPMENT, AND SUSTAINABLE EXCELLENCE BEYOND ENERGY GENERATION

ITAIPU BINACIONAL: INNOVACIÓN Y DESARROLLO REGIONAL INTEGRADOS MÁS ALLÁ DE LA GENERACIÓN DE ENERGÍA

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Resumo
A Itaipu Binacional é líder global em energia limpa, gerando não apenas imensa energia elétrica desde 1973, mas também conhecimento estratégico que impulsiona o desenvolvimento regional. A empresa lidera inovações significativas, exemplificadas pelo seu Projeto de Atualização Tecnológica - o maior investimento desde a sua fundação - e pela gestão estratégica da segurança de barragens, da longevidade de reservatórios e da cibersegurança. No entanto, essas iniciativas são frequentemente analisadas isoladamente. Esta pesquisa busca preencher essa lacuna, analisando e integrando sistematicamente os principais ativos de conhecimento e as iniciativas de desenvolvimento sustentável da Itaipu. Por meio de uma revisão estruturada de relatórios técnicos, publicações corporativas e literatura científica, a principal contribuição deste estudo é a sistematização desses ativos díspares em uma estrutura coesa. A análise revela que a sinergia entre o investimento de capital de longo prazo em modernização tecnológica e ativos intangíveis cruciais - ou seja, décadas de experiência operacional e uma cultura de sustentabilidade proativa - constitui a principal vantagem inovadora da Itaipu. Este modelo integrado comprova que as práticas sustentáveis são centrais, e não periféricas, para alcançar a excelência operacional e a resiliência a longo prazo no setor energético. Consequentemente, esta pesquisa fornece um modelo replicável para outros projetos de infraestrutura de grande escala em todo o mundo, oferecendo um caminho validado para alinhar a produção massiva de energia com os objetivos abrangentes de desenvolvimento sustentável.
Palavras-chave: Atualização Tecnológica; Desenvolvimento Regional; Inovação; Itaipu Binacional; Setor Elétrico.

Abstract
Itaipu Binacional is a global leader in clean energy, generating not only immense electrical power since 1973 but also strategic knowledge that fosters regional development. The company spearheads significant innovation, exemplified by its Technological Update Plan (TUP) – the largest investment since its inception – and strategic management of dam safety, reservoir longevity, and cybersecurity. However, these initiatives are often viewed in isolation. This research addresses this gap by systemically analyzing and integrating Itaipu's primary knowledge assets and sustainable development initiatives. Through a structured review of technical reports, corporate publications, and peer-reviewed literature, this study's primary contribution is the systematization of these disparate assets into a cohesive framework. The analysis reveals that the synergy between long-term capital investment in technological modernization and crucial intangible assets—namely, decades of operational expertise and a proactive sustainability culture—constitutes Itaipu's core innovative advantage. This integrated model proves that sustainable practices are central, not peripheral, to achieving long-term operational excellence and resilience in the energy sector. Consequently, this research provides a replicable blueprint for other large-scale infrastructure projects globally, offering a validated pathway to align massive energy production with overarching sustainable development goals.
Keywords: Electric Power Sector; Innovation; Itaipu Binacional; Regional Development; Technological Update Plan.

Resumen
Itaipu Binacional es líder mundial en energía limpia, generando no solo una inmensa cantidad de energía eléctrica desde 1973, sino también conocimiento estratégico que impulsa el desarrollo regional. La empresa lidera una importante innovación, ejemplificada por su Proyecto de Actualización Tecnológica —la mayor inversión desde su creación— y la gestión estratégica de la seguridad de las represas, la longevidad de los embalses y la ciberseguridad. Sin embargo, estas iniciativas suelen considerarse de forma aislada. Esta investigación aborda esta brecha mediante el análisis e integración sistemáticos de los principales activos de conocimiento y las iniciativas de desarrollo sostenible de Itaipu. A través de una revisión estructurada de informes técnicos, publicaciones corporativas y literatura revisada por pares, la principal contribución de este estudio es la sistematización de estos activos dispares en un marco coherente. El análisis revela que la sinergia entre la inversión de capital a largo plazo en modernización tecnológica y los activos intangibles cruciales —a saber, décadas de experiencia operativa y una cultura de sostenibilidad proactiva— constituye la principal ventaja innovadora de Itaipu. Este modelo integrado demuestra que las

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prácticas sostenibles son fundamentales, no secundarias, para lograr la excelencia operativa y la resiliencia a largo plazo en el sector energético. En consecuencia, esta investigación proporciona un modelo replicable para otros proyectos de infraestructura a gran escala en todo el mundo, ofreciendo una vía validada para alinear la producción masiva de energía con los objetivos generales de desarrollo sostenible.
Palabras clave: Actualización Tecnológica; Desarrollo Regional; Innovación; Itaipu Binacional; Sector Eléctrico.

1. Introduction

Since its establishment in the 1970s, Itaipu Binacional has been a significant source of knowledge and technological advancements. A testament to its commitment to modernization is the planning for its Technological Update Plan (TUP), which began in 2008. The bidding process for its execution was finalized in 2022, resulting in the formation of a binational consortium composed of Brazil's GE Consortium and the Paraguayan firms Tecnoedil and CIE. This endeavour is considered the largest and most complex project at the Itaipu Hydroelectric Power Plant since its original construction, valued at BRL 3.2 billion with a 14-year execution timeline (ITAIPU BINACIONAL, 2023).

Itaipu Binacional is an entity of public international law, created and governed by the Treaty of Itaipu to manage the hydroelectric resources of the Paraná River, which are held in condominium by the Republic of Paraguay and the Federative Republic of Brazil. The plant commenced commercial operations in May 1984, with an installed capacity of 14 gigawatts (GW), and has since generated over 3 billion megawatt-hours (MWh). (ITAIPU BINACIONAL, 2023).

Following forty years of continuous operation, the plant maintains high productivity levels, with availability indices aligned with or exceeding global industry standards. This sustained performance provides the empirical context for the current technological transition, moving beyond traditional engineering metrics to encompass a multidimensional strategy of asset management and regional integration.

Beyond its technological modernization, the company demonstrates benchmark performance in the environmental and social spheres, which, alongside electrical engineering, are core components of Itaipu Binacional's organizational mission: “To generate quality electricity with social and environmental responsibility,

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contributing to sustainable development in Brazil and Paraguay" (ITAIPU BINACIONAL, 2024). Furthermore, the company possesses nationally and internationally recognized expertise in critical areas of science, technology, and innovation, including dam safety, international relations, information technology, and corporate governance (ITAIPU BINACIONAL, 2023).

To address the conceptual complexity of Itaipu's innovation capacity, this study operationalizes knowledge assets through a five-dimensional taxonomy: (i) Technological Assets, encompassing digital modernization frameworks and high-level engineering expertise; (ii) Organizational Assets, including corporate governance protocols and advanced management systems; (iii) Relational Assets, defined by binational diplomatic cooperation and quadruple-helix collaborations; (iv) Territorial Assets, comprising localized socio-environmental expertise and watershed management practices; and (v) Reputational Assets, evidenced by international certifications and global performance benchmarks. This classification prevents the uncritical aggregation of institutional initiatives, ensuring that each asset is evaluated based on its specific strategic contribution to the Regional Innovation System (RIS).

The process of technology transfer—the transmission of technical knowledge—can yield both financial and non-financial advantages, such as through non-monetary licensing agreements that benefit all parties (QUINTELLA et al, 2019). As noted by Canongia and Antunes (2018), technological innovation is increasingly essential for maintaining organizational competitiveness.

This study is theoretically anchored in the Regional Innovation System (RIS) framework, conceptualizing Itaipu Binacional as a 'technological and institutional anchor.' By adopting this lens, the research moves beyond a descriptive inventory, framing the company's knowledge management and modernization efforts as systemic catalysts for regional learning and territorial resilience. Within this overarching architecture, ancillary concepts—such as the Quadruple Helix, intangible assets, and transboundary governance—function as supporting components that elucidate how a large-scale infrastructure project coordinates technical and social value creation. Consequently, the primary objective of this

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paper is to analyze Itaipu's knowledge assets and sustainability initiatives as benchmarks within an integrated regional innovation architecture, complemented by a scientific prospection of global trends in the electric sector.

2. Methodology

The study was executed through a structured protocol divided into three primary phases: (i) identification and database searching; (ii) screening and eligibility based on pre-defined criteria; and (iii) synthesis of evidence for benchmarking purposes. A temporal delimitation from 2019 to 2024 was applied to ensure the inclusion of the most recent technological developments and governance data. The selection process was governed by specific inclusion criteria: studies must focus on technological modernization (e.g., TUP), regional sustainability initiatives, or binational governance models. Exclusion criteria were applied to records focusing strictly on electricity market pricing, historical legal disputes unrelated to current innovation, or papers lacking full-text availability.

Furthermore, an institutional benchmarking analysis (previously referred to as expertise diagnosis) was performed. This phase involved a critical examination of Itaipus 2022 and 2023 Annual Reports to identify performance indicators that exceed international industry standards. These indicators—specifically in domains such as generating unit availability, dam safety, and cybersecurity compliance—served as the empirical basis for validating the plants status as a global benchmark.

The research workflow is visually summarized in Figure 1, which employs a modified PRISMA flow diagram (Page et al., 2021) to ensure transparency and reproducibility in the transition from the initial 1,750 records to the final selection of 32 core studies.

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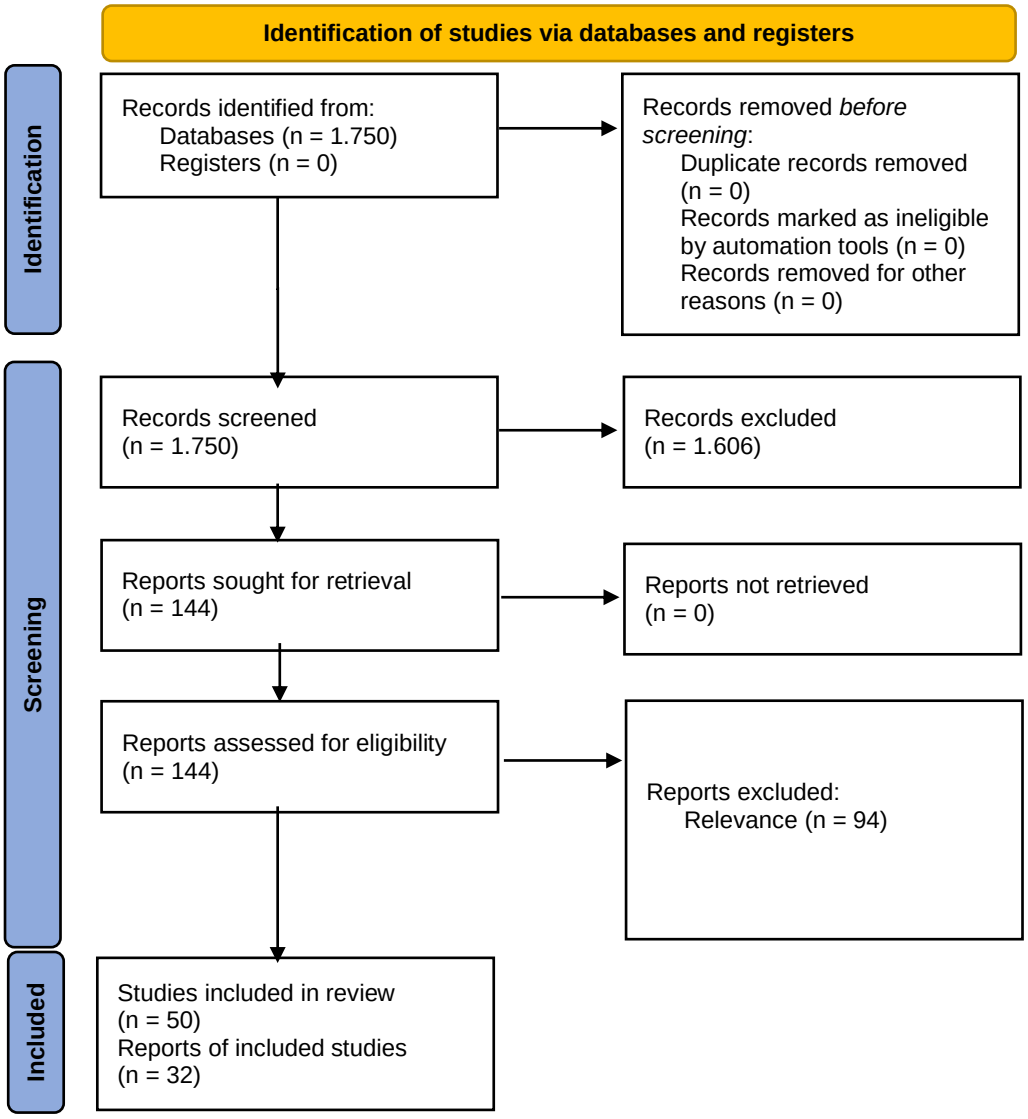

Figure 1 – Methodology of scientific prospecting and construction of the analysis. Source: Adapted by Page et al. (2021)

To ensure conceptual and terminological stability, this study consistently utilizes the term Technological Update Plan (TUP). The thematic frequency data presented in Table 3 were derived from a systematic qualitative content analysis of the final analytical corpus (n=32 studies).

The individual study served as the unit of analysis, and a multiple coding protocol was adopted, allowing a single record to be assigned to various categories depending on its thematic breadth. Consequently, the percentages represent the

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relative frequency of each theme across the total sample—for instance, an occurrence of 38% indicates that the theme was identified in 12 out of the 32 analyzed studies. This approach provides a transparent mapping of the current scientific landscape and the relative prominence of specific research domains.

The bibliographic search was structured around two thematic axes: intellectual assets and the electric sector. The search string utilized boolean logic: {("intellectual assets" OR "innovation" OR "technological update" OR "neoindustrialization") AND ("electrical sector" OR "hydroelectric plant" OR "hydroelectric")}.

This strategy, illustrated in Figure 2, combined terms within each group with the OR operator to broaden the search scope, while the two groups were linked with the AND operator to ensure the relevance of the results.

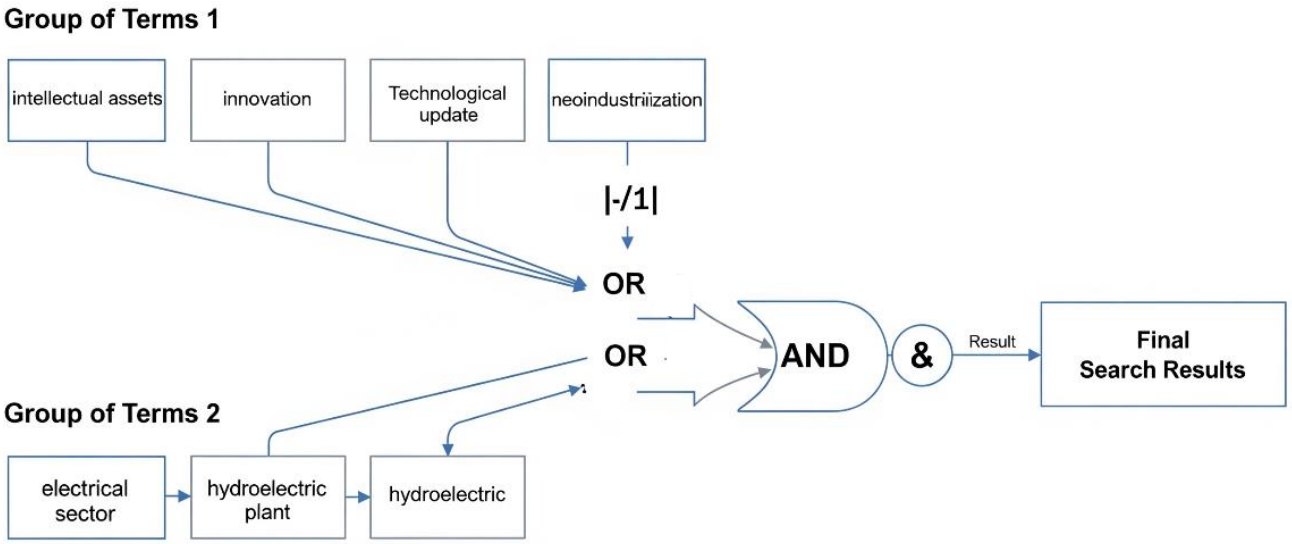

Figure 2 – Flowchart of the Keyword Search Strategy. Source: Authors (2025).

The bibliographic research, illustrated in Figure 2, shows how the two groups of terms were combined: (1) innovation and intellectual assets; (2) electric power sector. Within each group, the terms were linked using the OR operator to broaden the scope, while the two sets were connected using the AND operator to ensure alignment with the objectives and the relevance of the results.

The databases used for the bibliographic research were: Web of Science,

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ScienceDirect, SciELO, and Lens. For the documentary research: Itaipu Binacional's website; Google platform; and Big Data website. On Google, the results were restricted to PDF documents. A total of 1,750 articles were found, of which 144 specifically contained both groups of terms. From this selection, the 50 most relevant articles were chosen (through reading of titles and abstracts), and 32 of these were ultimately selected for this research.

The results present an analytically organized thematic structure, enabling a coherent presentation of technological achievements, social initiatives, and their regional implications (Sotuyo & Marques, 2015; Tartaruga, 2016). The subsequent sections detail these themes, providing a structured understanding of Itaipu Binacional's role in fostering innovation and development.

3. Results and Discussion

Section 3 is structured to clearly differentiate between the empirical findings of the scientific and documentary prospecting and the authors' interpretive synthesis. The results are categorized into three thematic axes: (i) the global electric sector context; (ii) the technical modernization of the TUP; and (iii) the regional development initiatives. Each axis begins with a presentation of the evidence gathered, followed by an analytical discussion that bridges the gap between raw institutional data and the proposed conceptual framework of integrated innovation.

Innovation in the Electric Sector

Approximately 85% of the world's energy supply comes from fossil sources such as coal, oil, and natural gas. Even in Brazil, where the electricity matrix is predominantly supplied by renewable sources, just over half of the primary energy supply still comes from fossil fuels (EPE, 2022). Primary sources are those directly derived from nature, before being converted into electricity, for example.

The electric power sector is the foundation of a country's industries, making it one of the most important economic sectors (Oliveira et al., 2019). Henrique et al. (2019) present electricity as one of the key sectors of Paraná's economy, in a study on the sectoral interconnections within the state's productive structure. Key sectors

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drive the economy by stimulating acquisitions and the supply of inputs to the production system.

Ensuring the safety of hydroelectric structures, along with reliable operation, is one of the main strategic actions for countries, particularly for the functioning of the energy, transportation, and agricultural sectors (Okhapkin & Vasilevskaya, 2022).

According to Gilardoni (2020), the term “energy transition” is reshaping the energy landscape, combining digitalization, the spread of renewable energies, and distributed generation, giving rise to a new paradigm to which essential or public utility services — simply known as “utilities” — must adapt according to their characteristics.

Hydropower is considered one of the most relevant renewable energy sources due to its numerous benefits, such as cost-effectiveness, the ability to reduce carbon emissions, and its potential for job creation compared to traditional fossil fuels. In addition, hydropower offers significant cost advantages over other types of renewable energy resources, including solar and wind energy, as pointed out by Ullah et al. (2024). Global hydropower production doubled between 1990 and 2020, reaching 4,345.99 TWh, and continues to show a growth trend.

According to the same authors, the hydropower sector holds a significant position in the global energy mix and is directly linked to financial development and economic progress, thus having substantial implications for achieving sustainable development — the theme and objective of their study.

Solarin and Ozturk (2015) investigated the directly proportional impact of hydropower production on economic development in Latin American countries. The authors’ long-term regression coefficients, covering the period from 1970 to 2012, suggest that hydropower consumption positively affects the economies of Argentina, Brazil, Chile, Colombia, Ecuador, Peru, and Venezuela. Chien et al. (2024) also demonstrate a similar result in China, in a historical analysis from 1981 to 2020, in which socioeconomic development and sustainable energy technologies, such as solar and hydropower, are significantly associated.

Hydropower generation capacity data indicate that approximately 70% of

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global hydropower is produced by just 10 countries (Table 1), with 50% of total production concentrated in China, Canada, Brazil, and the United States.

Table 1 – Main hydropower-producing countries

Share of Global Hydropower Generation			
China	18%	India	3%
Canada	12%	Norway	4%
Brazil	11%	Japan	3%
USA	9%	Sweden	2%
Russia	6%	Turkey	1%

Source: Adapted from ULLAH et al (2024).

Brazil plays an important role in global hydropower production, ranking third in this energy generation modality and contributing 11% to the global hydropower supply.

To ensure global comparability, the selection of international benchmarks followed three analytical criteria: (i) Operational Scale, targeting plants with massive installed capacity; (ii) Technological Frontier, focusing on 'Smart Hydro' and AI adoption; and (iii) Territorial Impact, identifying entities that manage energy within complex regional ecosystems. This structured approach enables a strategic contrast between Itaipu Binacional and global leaders such as the Gezhouba Hydroelectric Plant (China) and CVA (Italy), as synthesized in Table 5.

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Table 5 – Comparative Benchmarking of Global Hydroelectric Innovation

Entity (Country)	Digitalization & AI Maturity	Socio-Environmental Strategy	Innovation Focus
Itaipu Binacional (BR/PY)	Advanced (TUP, BIM, Cybersecurity compliance at 64.57%).	Integrated Territorial Management; Biodiversity protection (Life Certification).	Binational governance and regional sustainability.
Gezhouba (China)	High (Autonomous operation, 'Smart Plant' modularization).	Large-scale public policy integration.	Operational efficiency and centralized regulation.
CVA (Italy)	Intermediate (Predictive maintenance and EV infrastructure).	Community-centered; Glacier protection and consumer empowerment.	Climate change adaptation and regional integration.

While Gezhouba excels in the technological frontier of autonomous operation, Itaipu distinguishes itself by its multidimensional integration, where digital updates (TUP) are intrinsically linked to the longevity of the reservoir and the socio-economic resilience of the border region. This comparison highlights that Itaipu's innovative advantage lies in the complexity of its governance and the breadth of its territorial impact, whereas European and Asian models tend to focus on specific niches of digitalization or climate adaptation.

In summary, the results of this international prospecting indicate that while technological trends—such as digitalization and autonomous operation—are global constants, their success is mediated by local governance. The transition from these general industry findings to the specific analysis of Itaipu reveals that the plant’s status as a benchmark does not stem solely from adopting global technologies, but from the unique way it integrates these tools into a binational and territorial management model.

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Innovation at Itaipu Binacional: The Technological Update Plan

The literature on technological innovation and social initiatives by Itaipu Binacional reveals multiple approaches to regional development, encompassing economic, social, environmental, and geopolitical dimensions. Although several studies provide robust quantitative and qualitative analyses of Itaipu's contributions and challenges, there remains a gap in disseminating information about the company's technological achievements and their socio-environmental consequences.

Regarding technological innovation and regional impact, three studies were analysed that effectively document Itaipu's role as a technological pioneer, emphasizing its scale and contribution to renewable energy production, with detailed case analyses of the Itaipu Technology Park, which promotes eco-innovations and renewable energy niches (Carvalho & Cunha, 2021; Sotuyo & Marques, 2015). Quantitative models assess economic and social impacts, providing empirical evidence of Itaipu's influence on regional economies (Fruet et al., 2023).

Articles also highlight comprehensive social programs linked to Itaipu, emphasizing social initiatives and community engagement, such as the "Cultivando Água Boa" initiative, which integrates territorial realignment and community development (Ostrovski, 2014). These programs underscore the role of universities and technology parks as key agents in promoting social innovation and knowledge transfer (Sotuyo & Marques, 2015; Cobo-Gómez, 2023; Rashid et al., 2023).

Case studies of specific projects within the Itaipu Technology Park demonstrate the successful integration of technological innovation with social objectives, fostering renewable energy development and community engagement (Carvalho & Cunha, 2021; Antonovz et al., 2020). The park's model is presented as a replicable example of territorial innovation systems that promote regional development (Schmoeller et al., 2017; Maritan et al., 2024).

Several studies provide nuanced assessments of the socio-environmental and economic consequences of Itaipu's actions, including reservoir formation

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effects, demographic changes, and environmental degradation, contributing to a more holistic understanding of Itaipu's footprint (Steffen & Dias, 2024; Fan et al., 2022; Oliveira et al., 2016). Economic analyses incorporate multicriteria approaches to evaluate benefits and costs, linking them to corporate governance goals (Ortigoza et al., 2022).

In a Big Data search, the main result identified was the Itaipu Hydroelectric Plant TUP Workshop, held in October 2017. It was verified that the document is hosted on Itaipu Binacional's official website, as indicated by the itaipu.gov.br domain. According to the document released:

> The workshop aims to present the consolidated technical characteristics of the basic design for the Technological Update of the Itaipu Hydroelectric Plant, the scope of the project, and the main drivers of the bidding process, such as: contracting modality, consortium formation, technical, legal, and financial qualifications, among other issues (Itaipu Binacional, 2024d).

According to information published on Itaipu Binacional's website, in a specific section about the TUP, there were three meetings like the workshop mentioned:

> The first workshop, held in October 2017, was strictly technical, presenting a broader scope of the project to 140 companies in the sector. At that time, it was highlighted that the bidding process was divided into three lots: Lot 1, aimed at companies and consortia established in Brazil, and Lots 2 and 3, for those established in Paraguay.
>
> In the following year, also in October, a new workshop brought together the 21 companies most directly interested in the scope of the update. The topics addressed at this stage were both technical and legal in nature.
>
> By the end of 2018, the pre-qualification stage was completed, and only companies whose documentation had been fully approved were considered eligible and invited to this third meeting. For Lot 1, three consortia were qualified: Andritz-ABB, CATI (Voith, Siemens, and Tractebel), and GE (GE Hydro, Grid Soluções). For Lot 2, the qualified consortia and companies were: Consórcio Alto Paraná, Concret Mix S.A., Tecnoedil S.A., and Consórcio Proel-Ingelmec. The consortia qualified for Lot 3 were Rieder & Cia. and Consorcio de Ingeniería CIE S.A. (Itaipu Binacional, 2024c).

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It can be considered that the strategy of holding workshops constituted actions similar to Expert Panels. As cited by Antunes (2018), “expert panels are a method that brings together groups of people dedicated to analyzing and combining their knowledge about a specific area of interest.” Furthermore, expert panels are central processes in foresight exercises; they can take various forms and sizes and, in many cases, have their results published in reports. In Itaipu’s case, no reports from the TUP workshops were found in the databases used for this study.

The idea behind employing this type of strategy is to foster technological competitive intelligence, forecasting, tech foresight, technology prospecting, prospective studies, monitoring, and futures studies. All of these are terms related to business and technology information studies but with relevant distinctions, as presented by Antunes (2018) and through an extensive review of scientific literature on the subject (Table 2).

Table 2 – Main search results on competitive intelligence and foresight

Authors	Year	Authors	Year
Ansoff	1975	Miles, Keenan e Kaivo-Oja	2002
Porter A.	1991	Bahruth	2004
Porter M.	1991	Gilad	2004
Stoffels	1994	Marcial e Grumbach	2006
Leitão	1996	Georghiou	2008
Gavigan e Cahill	1997	Ashton e Hohhof	2009
Johnston	2000	Relatório UNIDO	2005
Godet	2000		

Source: Adapted from Antunes (2018).

Panels provide opportunities for interaction among participants, discussion of specific topics, and the generation of conclusions and recommendations based on the insights of experts. These experts must possess the minimum required knowledge to indicate how the topic under study will behave in the near future. For this reason, Antunes (2018) stresses that careful selection of panel participants is

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essential.

In the case of Itaipu's workshops, participants were systematically selected, as described in the announcement: "ITAIPU seeks for this event the participation of companies with proven capacity and experience in providing systemic solutions of the project's scale (…)." Even though there was a registration fee per participant, ITAIPU reserved the right to refuse the registration of companies that did not meet the profile and objectives of the event (Itaipu Binacional, 2024d).

The contract for the TUP of the Itaipu Hydroelectric Plant began execution in May 2022 with the development of the TUP, which comprised the management plans and the project's master schedule. Simultaneously, seven working groups, totaling 130 professionals — including participants from Itaipu and the binational consortium — began preparatory technical discussions for the next stages, which involve drafting the work statements and the Executive Projects.

In addition to these activities during the first months of the contract, laser scanning of all plant facilities within the scope of the TUP was initiated. The scanning process enables the creation of three-dimensional models of the plant, which will serve as the foundation for the executive projects using BIM (Building Information Modeling) technology (Itaipu Binacional, 2023).

Increasingly, Itaipu Binacional has used 3D printing as a tool for creating innovative solutions and improving electrical engineering processes; however, this topic is not within the scope of the TUP. In 2022, a total of 90 requests were designed, manufactured, and fulfilled, including spare parts that are already obsolete in the market. Among the created solutions, noteworthy examples include safety devices for locking 13.8 kV circuit breakers and components for field circuit breakers used in the Generating Units. These parts were showcased and stood out at the Congress promoted by the Brazilian Association of Maintenance and Asset Management (ABRAMAN) in September 2022.

Based on high-performance HMI (Human-Machine Interface) concepts, dynamic screens and graphics were developed and implemented in 2022 for the SCADA (Supervisory Control and Data Acquisition) supervision system and video wall. This implementation enabled significant improvements for the Load Dispatch

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teams, facilitating the identification of operational limits and productivity optimization, while adding greater situational awareness, operational predictability, and speed in identifying abnormal operating conditions (Itaipu Binacional, 2023).

Even after four decades of uninterrupted production — and without any major prior TUP process — Itaipu Binacional continues to present exceptional indicators, breaking productivity records and maintaining the availability of its Generating Units above both targets and market benchmarks. This is due not only to the high level of engineering excellence during the plants design and construction but also, to a large extent, to the increasingly efficient management of its energy production assets. According to the company's 2022 Annual Report:

> To ensure the continuity of this high performance, ITAIPU initiated this comprehensive technological update process, which includes the replacement, among others, of all power and control cables; the centralized control system; the protection and control systems of the Generating Units, the gas-insulated substation, and the spillway; auxiliary services; and the measurement and billing system. The Right Bank Substation, which connects ITAIPU to the Paraguayan electrical system and Furnas' direct current system, will also be modernized.
>
> The Technological Update Plan (PAT) also encompasses the construction of new warehouses and system integration centers; the acquisition of new management tools; and the contracting of support and consultancy services for project activities, inspection, supervision, and commissioning (Itaipu Binacional, 2023).

It is evident the high level of reference Itaipu holds in electric power production and what is expected from the PAT and all the technical expertise involved, with the continuation of the highest performance levels being the primary goal.

Itaipu Binacional's role in regional development is analyzed here through the lens of Territorial Innovation Systems (TIS), where the institution functions as an 'anchor organization' that catalyzes multidimensional changes in its border territory. To avoid a strictly descriptive or normative bias, this study distinguishes between four analytical categories of impact: (i) Direct Economic Drivers, such as local procurement and infrastructure investments; (ii) Institutional and Social Assets, comprising health systems (hospitals) and governance protocols; (iii)

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Environmental Ecosystem Services, related to watershed management and biodiversity; and (iv) Structural Innovation Externalities, specifically the knowledge transfer and technological densification promoted by the Itaipu Technological Park (PTI). By applying this matrix, the following evidence is interpreted not merely as isolated corporate social responsibility (CSR) initiatives, but as interconnected components of a long-term regional development strategy aimed at territorial resilience.

Table 3 presents the main scientific results published on Itaipu's innovation and governance:

Table 3 – Overview of Key Scientific Publications on Itaipu Binacional's Innovation and Governance

Theme	Occurrence	Theme Description	Authors
Technological innovation and regional economic development	38%	Research consistently highlights Itaipu Binacional's technological advances in hydropower and renewable energy technologies, emphasizing its role in promoting regional economic growth and industrial competitiveness. The integration of eco-innovative projects and technology parks demonstrates how technological innovation fosters local and regional development, supported by qualitative case studies and quantitative analyses.	(Carvalho & Cunha, 2021; Sotuyo & Marques, 2015; Pereira et al., 2023; Lubis & Sinaga, 2023; Maritan et al., 2024)
Social initiatives and community engagement	34%	Social programs and community engagement linked to Itaipu Binacional are recognized for promoting social inclusion, local capacity building, and quality of life improvements. Studies reveal how social innovation intersects with technological development to generate socioeconomic benefits, often through university-community partnerships and cooperative models promoting sustainable development and social entrepreneurship.	(Ostrovski, 2014; Polovko, 2022; Antonovz et al., 2020; Espiau, 2023; Cobo-Gómez, 2023; Rashid et al., 2023)
Regional socio-environmental impacts and governance	30%	The socio-environmental consequences of Itaipu's construction and operation, including displacement, ecological changes, and resource management conflicts, are thoroughly analyzed. Governance structures addressing transboundary water relations and equitable resource distribution are key issues, highlighting the complexities of binational cooperation and sociopolitical dimensions of regional development.	(Steffen & Dias, 2024; Berkhout & Warner, 2023; Storto & Cocato, 2017; Birch & Ashwell, 2010; Oliveira et al., 2016; Rohracher, 2006)
Role of academic and business stakeholders in innovation systems	24%	The involvement of universities, research institutions, and private companies in regional innovation systems is fundamental for promoting knowledge exchange, technology transfer, and sustainable innovation. The quadruple helix model and collaborative innovation strategies are frequently cited as effective mechanisms for regional development and aligning economic and social objectives.	(Sotuyo & Marques, 2015; "Innovation, Regional Development and the C...", 2023; Thomas et al., 2023; Fan et al., 2020)
Economic and political dimensions of Itaipu operations (contained in documents)	20%	Economic analyses focus on cost structures, treaty negotiations, and revenue distribution of Itaipu, particularly concerning Paraguay's economic benefits and challenges. Policy-oriented research	(Fruet et al., 2023; Ortigoza et al., 2022; Fernandez et

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Theme	Occurrence	Theme Description	Authors
		discusses the implications of these economic arrangements on regional development goals and sustainable development objectives.	al., 2016; Santos et al., 2013)
Innovation as a driver of sustainable regional development	18%	Broader literature positions technological and social innovation as fundamental to achieving sustainable development at the regional level, linking innovation ecosystems to environmental and social agendas. Multi-stakeholder collaborations and social innovation are identified as key factors in advancing sustainability and inclusive growth.	(Tartaruga, 2016; Mariani et al., 2022; Pesch et al., 2019)
Examples of technological and social projects at Itaipu	14%	Specific projects such as the Agroenergy Condominium, biogas initiatives, and technology park developments illustrate the successful integration of technology and social innovation, promoting renewable energy use, local economic diversification, and community empowerment.	(Osvaldo, 2011; Antonovz et al., 2020; Carvalho & Cunha, 2021)
Spatial and geopolitical context of Itaipu	12%	Itaipu Binacional's geopolitical positioning on the Brazil-Paraguay border shapes its strategic importance, influencing regional power relations, territorial development, and energy security. Historical and spatial analyses emphasize the role of state diplomacy and territorial production in shaping outcomes.	(Souza, 2011; Santos et al., 2013; Nickson, 2015)
Challenges in socio-environmental mitigation and cultural considerations	10%	Several studies critique the effectiveness of social and environmental mitigation measures, highlighting the need for culturally sensitive approaches and better stakeholder engagement. Failures in addressing indigenous rights and cultural dynamics reveal the complexities of impact management.	(Storto & Cocato, 2017; Oliveira et al., 2016)
Innovation efficiency and regional collaborative networks	8%	Empirical research indicates that collaborative innovation within and among regions increases overall innovation efficiency and socioeconomic outcomes, emphasizing the importance of networks and cooperation among regional actors.	(Fan et al., 2020; Gonçalves & Fajardo, 2011)

Source: Authors (2025)

Table 3 showed it is possible to verify that the literature on Itaipu Binacional integrates key themes of technological innovation, social development, and regional impact within the Brazil-Paraguay border context. The central discussions revolve around the technological achievements of the hydroelectric project and its implications for regional economic and social transformations. The involvement of academic and business stakeholders in promoting innovation alongside social initiatives highlights the complex interactions that shape regional sustainability and development. The studies also emphasize socio-environmental consequences and governance issues, revealing a multifaceted picture of Itaipu's role in regional dynamics and broader innovation ecosystems.

Regarding dam safety, the structural and physical performance of Itaipu Binacional remains excellent even after 40 years since the first filling, considered to

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be at the highest global safety level and compliant with Brazilian standards. The company continues to monitor and conduct specialized studies to analyze the behavior of earth, concrete, and rockfill dams, including the installation of additional instruments.

In the environmental area, Itaipu holds the Life Certification for biodiversity conservation, reaffirming and recognizing its ongoing work in protecting biodiversity. The company was the first in Paraguay to earn this quality seal for its environmental efforts toward sustainable resource use. In terms of watershed management, Itaipu seeks to reduce sediment inflow and extend the reservoir's useful life, currently estimated at 194 years (Itaipu Binacional, 2023).

Among its social development practices, noteworthy initiatives include strengthening family agriculture with 3,362 annual advisory services, monitoring 127 family agro-industries, supporting indigenous communities, promoting sports, and providing education for sustainability and citizenship. It is highlighted that in 2022, more than 240,000 people were impacted by the sustainability education program.

Still regarding social development, Itaipu Binacional is the founder and maintainer of two reference hospitals in Brazil and Paraguay. In Brazil, the Hospital Ministro Costa Cavalcanti provides a high volume of care to SUS patients, accounting for about 60% of its hospitalizations. It is the sole reference center for the 9th Health Regional of Paraná State in the fields of oncology, cardiology, high- and intermediate-risk pregnancy, and neonatology, in addition to performing 100% of routine obstetric care for the municipalities of Foz do Iguaçu and Santa Terezinha de Itaipu (Itaipu Binacional, 2023).

Regarding Itaipu Binacional's procurement, the indices are significant: 72.1% of total acquisitions come from local suppliers—defined as those established in Paraná State and throughout Paraguay—and 34.6% correspond to sustainable purchases, totaling 45.15 million dollars in 2022, excluding TUP costs (Itaipu Binacional, 2023). The company's Sustainable Procurement Policy results in some contracts meeting sustainability requirements, which materialize in the dissemination and encouragement of sustainability within Itaipu's supply chain.

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Concerning the availability of the corporate Information Technology (IT) environment, in 2022 it reached 99.94%, exceeding the planned index of 98% to meet strategic corporate objectives. This means that during the year there were only 5 hours, 20 minutes, and 37 seconds of unavailability in the productive environment. Regarding cybersecurity, Itaipu achieved compliance of 64.57%, configured as one of the main standards and best cybersecurity practices in the market, whose average was 43.41%, covering components from the ISO/IEC 27000 family, NIST SP 800-53 Rev.4, COBIT, CIS v8, and OWASP frameworks (Itaipu Binacional, 2023).

In terms of technological development, Itaipu has, among other initiatives, the Itaipu Technological Park (PTI), which it founded and maintains. PTI is a leading Science and Technology Institution located within the power plant area, featuring extensive infrastructure and a broad ecosystem composed of educational, research, business, and government institutions, as well as connections with other national and international innovation ecosystems.

The business model of Itaipu Binacional is considered a benchmark for international cooperation between nations. The official management model, defined in the Internal Regulations, is the Enterprise Planning and Control System (SPCE). Itaipu's administration is carried out jointly and on an equal basis by Paraguay and Brazil, the partner countries, represented respectively by the Administración Nacional de Electricidad (Ande) and, since 2022, by the Brazilian Nuclear and Binational Energy Holdings Company (ENBPar), which succeeded Centrais Elétricas Brasileiras S.A. (Eletrobras).

Following internationally established corporate governance practices, Itaipu has structured the following mechanisms: the Ethics Committee, a channel available for complaints managed by a binational collegiate; Compliance Advisory services to implement strategic, tactical, and operational actions focused on Integrity and Compliance; and Ombudsman offices, which serve as interaction spaces between society and Itaipu, strictly observing the defense of human rights and human dignity, guided by ethical and moral principles, respect for legal norms, and the constitutional principles of Paraguay and Brazil. These mechanisms serve

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as channels for continuous improvement of Itaipu's institutional management, aiming to benefit companies in Paraguay, Brazil, and the entire society involved.

Regarding internal management, some notable actions include the Legal Directorates TUP, which involved cleaning the legal system database and developing dashboards, allowing greater security and credibility of information extracted from the system, standardization and systematization of strategic data, and obtaining reliable indicators for improved decision-making. The consolidation of the Legal Controllership is also noteworthy, as it enabled the standardization of data collection and recording activities, increasing efficiency in information processing.

To synthesize the relationship between these heterogeneous evidence sets and the proposed conceptual framework, Table 4 organizes the findings into four strategic pillars. This categorization demonstrates how specific empirical actions—from engineering investments to governance protocols—interconnect to form an integrated model of sustainable innovation.

Table 4 – Conceptual Pillars of the Itaipu Sustainable Innovation Model

Strategic Pillar	Empirical Basis & Key Evidence	Integrative Contribution to the Model
1. Digital & Technological Modernization	Technological Update Plan (TUP); BIM technology; $3.2B investment; 3D printing for obsolete parts.	Drives **Operational Excellence** by transitioning from analog to digital infrastructure, ensuring asset longevity.
2. Technical Expertise & Risk Management	Dam safety protocols (40-year performance); Cybersecurity compliance (64.57%); AI-driven maintenance.	Converts decades of operational data into **Intangible Assets**, enhancing resilience against systemic and digital risks.
3. Sustainable Regional Development	Life Certification (Biodiversity); Watershed management (sediment reduction); 240,000+ people impacted by education.	Links **Environmental Longevity** with territorial health, positioning sustainability as a core operational requirement.

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Strategic Pillar	Empirical Basis & Key Evidence	Integrative Contribution to the Model
4. Collaborative Binational Governance	Treaty of Itaipu framework; SPCE management system; Ethics and Compliance collegiate.	Provides the **Institutional Stability** and ethical transparency necessary for large-scale international cooperation.

Analytical Synthesis: Convergences and Critical Ambivalences

The consolidation of Itaipu as a global benchmark requires a balanced synthesis that integrates institutional excellence with critical territorial realities. While corporate data indicates record-breaking productivity and high-level cybersecurity compliance, academic research emphasizes the projects complex socio-environmental footprint, including historical displacement of indigenous and local communities and the long-term ecological effects of reservoir formation. These tensions are not peripheral but constitutive of the binational models governance challenges.

The innovation advantage discussed in this study must, therefore, be understood as a dynamic process of mediation, where institutional maturity is measured by the capacity to acknowledge and respond to socio-political asymmetries and environmental externalities.

Rather than presenting corporate indicators as absolute proof of success, this analysis suggests that Itaipu's benchmark status lies in its ongoing effort to align massive energy production with the complex and often conflicting demands of regional sustainability and social justice. This critical mediation ensures that the technological updates described in the TUP are not merely engineering achievements but tools within a broader, and at times ambivalent, socio-technical system."

4. Conclusions and Recommendations

In line with the objective of this research, which was to present the main knowledge assets and corporate sustainability initiatives of Itaipu Binacional, a

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range of knowledge and initiatives have been presented that together comprise a portfolio of assets available to the company. These serve as references in scientific prospecting and can be cited and referenced in future studies and/or initiatives by other institutions.

It is essential to highlight the importance of knowledge in today's society, often described as the knowledge society, where industry increasingly values intellectual assets as one of the most important means of achieving wealth.

The systematization of Itaipu Binacional's knowledge assets offers a strategic framework for understanding the integration of innovation within large-scale energy infrastructure. However, a critical distinction must be made between the plant's non-transferable institutional exceptionality—dictated by its unique binational treaty and historical geopolitical role—and its methodological exemplarity.

The replicability of this model resides not in its legal architecture, but in its transferable strategic processes, such as the digital transition through BIM (TUP) and the operationalization of Territorial Innovation Systems (TIS). By identifying these scalable management pathways, the study provides a documented reference for other 'anchor-institutions' to synchronize industrial performance with regional resilience, while acknowledging the inherent constraints of its specific transboundary context.

The systematization of Itaipu Binacional's knowledge assets presented in this study offers a strategic framework for understanding how large-scale energy infrastructure can integrate innovation with territorial development. However, the unique binational legal status and the specific historical context of the plant necessitate a cautious approach toward the universal generalization of these findings. Rather than an 'incontestable' blueprint, the proposed model serves as a documented reference of integrated management practices that can inform similar initiatives in the energy sector. Future research agendas should expand upon this by conducting comparative analyses with other global hydroelectric entities and incorporating longitudinal assessments of the socio-economic impacts of the TUP. This would allow for a more robust refinement of the analytical categories proposed

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and address the inherent complexities of sustainable energy transitions in transboundary contexts.

Acknowledging the methodological constraints of this study is essential for maintaining academic integrity. A significant portion of the evidence regarding operational excellence and sustainability performance was derived from Itaipu Binacional's official corporate reports. While these documents follow international transparency and binational audit standards, their nature as self-reported primary sources introduce a potential risk of document bias. To mitigate this, this research employed a triangulation strategy, contrasting institutional indicators with independent peer-reviewed literature and global energy sector benchmarks wherever available. Nevertheless, the findings presented here should be interpreted as a synthesis of reported institutional success and independent academic observation. Future research is encouraged to incorporate longitudinal field data and multi-stakeholder interviews to further validate these results through external, non-institutional perspectives.

The published literature on Itaipu Binacional highlights the complex and multifaceted influence of its technological innovations and social initiatives on regional development in the Brazil-Paraguay border region. Collectively, these studies demonstrate that Itaipu's technological advancements, particularly through renewable energy production and the establishment of innovation ecosystems such as the Itaipu Technological Park, have catalyzed significant economic and social transformations. The creation of technology centers and collaboration among universities, companies, and government entities have promoted eco-innovation and supported regional competitiveness, confirming the park's role as a territorial innovation system.

Simultaneously, the social initiatives associated with Itaipu present mixed results. Effective programs, such as social entrepreneurship models, agroenergy cooperatives, and university-community partnerships, have fostered sustainable local development and community engagement.

The literature presents Itaipu Binacional as a case of large-scale technological infrastructure projects interconnected with social innovation and

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regional development. These technological achievements have laid the foundation for economic growth and innovation, while current governance challenges should focus on valuing its economic assets.

References

Antonovz, T., Correa, M. D., & Costa, M. C. (2020). Inovação social e desenvolvimento local: Uma análise em um condomínio de agroenergia para a agricultura familiar. Business and Management Studies, 6(4), 1–11. https://doi.org/10.11114/BMS.V6I4.5096

Antunes, A. M. S., et al. (2018). Métodos de prospecção tecnológica, inteligência competitiva e foresight: Principais conceitos e técnicas. In N. M. Ribeiro (Org.), Prospecção tecnológica (1st ed., pp. 19–99). Editora do Instituto Federal da Bahia (EDIFBA). http://www.profnit.org.br/pt/livros-profnit/

Areas, P. O., & Frey, I. A. (2019). O que é permitido fazer com a tecnologia. In I. A. Frey, J. Tonholo, & C. M. Quintella (Orgs.), Conceitos e aplicações de transferência de tecnologia (1st ed., pp. 44–102). Editora do Instituto Federal da Bahia (EDIFBA). http://www.profnit.org.br/pt/livros-profnit/

Berkhout, P., & Warner, J. (2023). Cross-border water relations of the Itaipu Dam. Regions and Cohesion, 13(3), 15–33. https://doi.org/10.3167/reco.2023.130302

Birch, M. H., & Ashwell, N. Q. (2010). Water worth gold: The Itaipu hydro-electric project. In Cases in Management (pp. 57–76). Springer. https://doi.org/10.1007/978-90-481-9920-4_4

Carvalho, A. D. P., & Cunha, S. K. D. (2021). Itaipu Technological Park: An ecoinnovative niche for renewable energies. IntechOpen. https://doi.org/10.5772/INTECHOPEN.95980

Chien, F., Chau, K. Y., & Huang, X. C. (2024). The perceived relationship between sustainable energy technologies, eco-innovation, economic growth and social sustainability: Evidence from China. Technological and Economic Development of Economy, 30(3), 1109–1132. https://journals.vilniustech.lt/index.php/TEDE/article/view/20445

Cobo-Gómez, J. C. (2023). Social innovation in university-community partnerships in Latin America: Exploring collaborative models. Sustainable Technology and Entrepreneurship, 2(3), 100061. https://doi.org/10.1016/j.stae.2023.100061

Du, Y., Xu, F., & Du, C. (2020, November 23-25). Research on the operation management mode of intelligent hydroelectric power plant [Conference presentation]. 2020 IEEE Sustainable Power and Energy Conference (iSPEC), Chengdu, China. https://doi.org/10.1109/iSPEC50848.2020.9351258

REMUNOM
ISSN 2178-6925

Received: 13/01/2026 - **Accepted:** 27/04/2026
Vol: 13.07
DOI: 10.66104/q9esmz05
Pages: 1-30

Empresa de Pesquisa Energética (EPE). (2022). Balanço energético nacional 2022: Ano base 2021. EPE. https://www.epe.gov.br/sites-pt/publicacoes-dados-abertos/publicacoes/PublicacoesArquivos/publicacao-675/topico638/BEN2022.pdf

Espiau, I. G. (2023). Cooperatives and social innovation. In Elgar Encyclopedia of Technology and Society. Edward Elgar Publishing. https://doi.org/10.4337/9781800373358.ch55

Espinola, M. O. G. (2011). Estudo técnico-econômico do aproveitamento da energia turbinável proveniente do vazamento da barragem de Itaipu para a produção de amônia. Revista Internacional de Engenharia Energética e Ambiental, 2(2), 57–64. https://repositorio.unicamp.br/handle/REPOSIP/438003

European Commission. (2009). Metrics for knowledge transfer from public research organisations in Europe. Publications Office of the European Union. https://op.europa.eu/en/publication-detail/-/publication/b1b369c3-433c-411a-a8c6-b333446b08e7

Fan, F., Lian, H., Wang, X., & Liu, X. (2020). Can regional collaborative innovation improve innovation efficiency? An empirical study of Chinese cities. Growth and Change, 51(1), 440–463. https://doi.org/10.1111/grow.12346

Fan, P., OMeara, B. F., & Chen, J. (2022). Newly constructed hydroelectric dams are associated with reduced economic production, population, and vegetation in nearby areas. Proceedings of the National Academy of Sciences of the United States of America, 119(8), e2108038119. https://doi.org/10.1073/pnas.2108038119

Fernandez, F., de Morais, A. P., Bezerra, J. M. B., Costa, E. A. C., & da Silva, R. B. A. (2016, June 15-17). Implementation of a control layer based on IEC 61850 for the Itaipu hydropower plant physical model [Conference presentation]. 2016 IEEE Biennial Congress of Argentina (ARGENCON), Buenos Aires, Argentina. https://doi.org/10.1109/ARGENCON.2016.7585355

Fruet, V., Campos, D., & Caridad, L. (2023). Itaipu Binational Dam: A quantitative analysis of the economic and social impacts in Paraguay. Successful or not? SAGE Open, 13(4). https://doi.org/10.1177/21582440231216820

Gilardoni, A. (Ed.). (2020). The Italian utilities industry. Springer. https://link.springer.com/book/10.1007/978-3-030-37677-2

Girolamo, E. de. (2020). CVA: Renewable sources value chain in the experience of a leading hydroelectric player in Italy. In A. Gilardoni (Ed.), The Italian utilities industry (pp. 111–123). Springer. https://doi.org/10.1007/978-3-030-37677-2_10

Gonçalves, E., & Fajardo, B. D. A. G. (2011). A influência da proximidade tecnológica e geográfica sobre a inovação regional no Brasil. Revista de Economia Contemporânea, 15(1), 112–142. https://doi.org/10.1590/S1415-

REMUNOM
ISSN 2178-6925

Received: 13/01/2026 - **Accepted:** 27/04/2026
Vol: 13.07
DOI: 10.66104/q9esmz05
Pages: 1-30

98482011000100005

Henrique, F., Diniz Filho, E. T., da Cruz, F. M., & da Silva, M. W. (2019). Estrutura produtiva do estado do Paraná e identificação de setores-chave para o desenvolvimento. Revista Brasileira de Gestão e Desenvolvimento Regional, 15(7), 89–106. https://www.rbgdr.net/revista/index.php/rbgdr/article/view/5270

Iaccarino, A., Frazzica, A., Ferraro, M., & Antonucci, V. (2023). How disruptive artificial intelligence solutions can enhance safety of field operations in the electrical sector [Conference presentation]. 8th International Conference on Power and Energy Systems Engineering (CPESE 2023), Toki, Japan. https://ieeexplore.ieee.org/document/10267705

Itaipu Binacional. (2023). Relatório anual Itaipu Binacional 2022. https://www.itaipu.gov.br/sites/default/files/af_df/RelAnual_2022_.pdf

Itaipu Binacional. (2024a). Apresentação (Universidade corporativa). https://www.itaipu.gov.br/tecnologia/apresentacao

Itaipu Binacional. (2024b). Itaipu apresenta projeto de atualização tecnológica às empresas pré-qualificadas. https://www.itaipu.gov.py/sala-de-imprensa/noticia/itaipu-apresenta-projeto-de-atualizacao-tecnologica-empresas-pre-qualificad

Itaipu Binacional. (2024c). Relatório anual Itaipu Binacional 2023. https://www.itaipu.gov.br/sites/default/files/af_df/Relatorio_Anual_Itaipu2023_Portugues.pdf

Itaipu Binacional. (2024d). Workshop atualização tecnológica. https://www.itaipu.gov.br/sites/default/files/af_df/Workshop_Atualizacao_Tech.pdf

Li, K. (2023). Role of digital economic development in environmental transition of renewable energy sector of China. Environmental Science and Pollution Research, 30, 111409–111419. https://doi.org/10.1007/s11356-023-30582-w

Lubis, P. S. A., & Sinaga, S. S. (2023). Inovasi teknologi dalam kewirausahaan: Membangun ekosistem bisnis berkelanjutan melalui pelatihan kewirausahaan digital. Jurnal Ekonomi, Bisnis dan Manajemen, 3(1), 281–290. https://doi.org/10.58192/ebismen.v3i1.1792

Mariani, L., Machado, C., & Pizzetti, M. (2022). Achieving sustainable development goals through collaborative innovation: Evidence from four European initiatives. Journal of Business Ethics, 180(4), 1075–1095. https://doi.org/10.1007/s10551-022-05193-z

Maritan, F. B., Nakao, A. Y., da Silva, A., de Souza, B. L. C., & Costa, I. (2024). Regional development through innovation: A proposal for a technological hub framework. GeSec, 15(10), e4255. https://doi.org/10.7769/gesec.v15i10.4255

REMUNOM
ISSN 2178-6925

Received: 13/01/2026 - **Accepted:** 27/04/2026
Vol: 13.07
DOI: 10.66104/q9esmz05
Pages: 1-30

Nickson, R. A. (2015). The Itaipu hydroelectric project: The Paraguayan perspective. Latin American Bureau.

Okhapkin, G., & Vasilevskaya, L. S. (2023). Analysis of approaches to the choice of methods for applying or laying repair materials for the concrete restoration of hydro-technical facilities. Power Technology and Engineering, 56, 730–736. https://doi.org/10.1007/s10749-023-01517-9

Oliveira, C., Cândido, T., & Lima, B. (2019). The incidence of innovation in corporate social responsibility in the companies of the electrical sector. International Journal of Innovation, 7(2), 221–241. https://doi.org/10.5585/iji.v7i2.16486

Oliveira, P. D., Cunha, L. H., & Ferreira, L. C. (2016). The importance of cultural aspects in impact assessment and project development: Reflections from a case study of a hydroelectric dam in Brazil. Impact Assessment and Project Appraisal, 34(4), 306–318. https://doi.org/10.1080/14615517.2016.1184501

Ortigoza, E., Enciso, M., & Martinez, L. (2022, October 24-28). Application of the perceptor hierarchical model to the negotiations on the cost of electricity service of a binational hydropower plant: The case of ITAIPU [Conference presentation]. 2022 IEEE International Conference on Automation/XXV Congress of the Chilean Association of Automatic Control (ICA-ACCA), Curicó, Chile. https://doi.org/10.1109/ICA-ACCA56767.2022.10006116

Ostrovski, D. (2014). Itaipu binacional: Implantação, reflexos socioambientais e territoriais. Percurso, 6(2), 195–218. https://doi.org/10.4025/revpercurso.v6i2.23290

Pereira, R. M., da Silva, I. Y. C., & Torkomian, A. L. V. (2024). Technological intensity and local socio-economic development. Journal of International Development, 36(4), 1085–1106. https://doi.org/10.1002/jid.3853

Pesch, U., Spekkink, W., & Quist, J. (2019). Local sustainability initiatives: Innovation and civic engagement in societal experiments. European Planning Studies, 27(2), 300–317. https://doi.org/10.1080/09654313.2018.1464549

Polovko, S. (2022). The role of social entrepreneurship and social innovation in regional development. Rural Development 2021: Challenges for Sustainable Bioeconomy and Climate Change, 409–413. https://doi.org/10.15544/rd.2021.070

Quintella, C. M., Teodoro, A. F., & Frey, A. F. (2019). Vantagens econômicas da transferência de tecnologia. In I. A. Frey, J. Tonholo, & C. M. Quintella (Orgs.), Conceitos e aplicações de transferência de tecnologia (1st ed., pp. 103–138). Editora do Instituto Federal da Bahia (EDIFBA). http://www.profnit.org.br/pt/livros-profnit/

Rashid, N. K. A., et al. (2023). Community engagement and social innovation

REMUNOM
ISSN 2178-6925

Received: 13/01/2026 - **Accepted:** 27/04/2026
Vol: 13.07
DOI: 10.66104/q9esmz05
Pages: 1-30

through knowledge transfer: Micro evidence from Setiu fishermen in Terengganu, Malaysia. Journal of the Knowledge Economy. Advance online publication. https://doi.org/10.1007/s13132-023-01102-5

Rohracher, H. (2006). Governing sociotechnical change in regional innovation systems. Science, Technology, & Human Values, 31(6), 687–704. https://doi.org/10.1177/0162243906291880

Santos, T., Haliu, A., & Coviello, M. (2013). Energy security and binational cooperation: A case study of the Itaipu dam. Integration & Trade Journal, 17(36), 105–115. https://ideas.repec.org/a/idb/intala/jouintegandcomv36y2013i17p105-115.html

Schmoeller, A., Costa, P. R., Miranda, V. D. S., & Leite, Y. V. P. (2017). Estratégia de desenvolvimento regional: análise do parque tecnológico de itaipu como um sistema local de inovação regional. Revista Orbis Latina, 7(2), 172–191. https://www.revistas.unila.edu.br/orbis/article/view/979

Solarin, S. A., & Ozturk, I. (2015). On the causal dynamics between hydroelectricity consumption and economic growth in Latin America countries. Renewable and Sustainable Energy Reviews, 52, 1857–1868. https://doi.org/10.1016/j.rser.2015.08.020

Sotuyo, J. C., & Marques, M. A. J. (2015). Itaipu technology park: A territorial development tool. In C. E. E. Staff (Ed.), Procedia - Social and Behavioral Sciences, 195, (pp. 71-77). Elsevier. https://doi.org/10.1016/j.sbspro.2015.06.150

Souza, E. B. C. D. (2011). A geopolítica da produção do espaço: Localização da hidrelétrica da Itaipu Binacional. Geografares, 9, 141-167. https://doi.org/10.7147/GEO9.1356

Steffen, N. C., & Dias, E. D. S. (2024). Processo de implantação da usina hidrelétrica de Itaipu Binacional e suas consequências socioambientais no espaço da fronteira Brasil - Paraguai. Revista Verde Grande: Geografia e Produção do Conhecimento no Cerrado, 6(1), 482–511. https://doi.org/10.46551/rvg26752395220241482511

Storto, C., & Cocato, G. P. (2017). Usina hidrelétrica de Itaipu: Uma perspectiva a respeito dos seus impactos socioambientais. Geografia (Londrina), 26(3), 205-224. https://doi.org/10.5433/2447-1747.2017v26n3p205

Tartaruga, I. G. P. (2016). Innovaciones sociales e inclusivas: Límites y posibilidades para el desarrollo territorial en el contexto de la globalización (Texto para Discussão, 146). Fundação de Economia e Estatística. https://arquivofee.rs.gov.br/wp-content/uploads/2016/06/20160601td-146-innovaciones-sociales-e-inclusivas_-limites-y-posibilidades-para-el-desarrollo-territorial-en-el-contexto-de-la-globalizacion.pdf

REMUNOM
ISSN 2178-6925

Received: 13/01/2026 - **Accepted:** 27/04/2026
Vol: 13.07
DOI: 10.66104/q9esmz05
Pages: 1-30

Thomas, E., Pugh, R., & MacKenzie, N. (2023). Beyond ambidexterity: Universities and their changing roles in driving regional development in challenging times. The Journal of Technology Transfer, 49, 1629–1648. https://doi.org/10.1007/s10961-022-09992-4

Ullah, A., Guo, J., Tan, X., & Ahmed, M. (2024). Exploring the nexus among hydroelectric power generation, financial development, and economic growth: Evidence from the largest 10 hydroelectric power-generating countries. Energy Strategy Reviews, 52, 101323. https://doi.org/10.1016/j.esr.2024.101323