Green Energy Entrepreneurship and Innovation in Latin America and the Caribbean (2020–2024): A Bibliometric Mapping of Research Themes

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Abstract– The present study maps 308 peer reviewed publications on green energy entrepreneurship and innovation in Latin America and the Caribbean from 2020 to 2024. Using a harmonized keyword strategy and standard bibliometric mapping, it identifies a clear energy center around renewable energy, solar and wind, hydrogen, energy storage, and power system integration within a frame of sustainability, climate, and circular economy. A three-field view linking topics, countries, and affiliations highlights a focused set of university hubs, with Brazil leading output and Mexico and Colombia as steady partners connected to Spain and Portugal. The thematic map places energy storage and business models near the center as bridges to market uptake, while energy transition and energy sources act as basic anchors and specialized lines remain in niche areas. Taken together, the results offer a practical path to align research, regulation, and investment so that storage and sound business models, supported by coordinated hubs and fit for purpose policy and finance, help move green energy from pilots to wider adoption across the region.

Keywords: Renewable energy; Energy storage; Business models; Sustainable entrepreneurship; Latin America and the Caribbean.

I. Introduction

The energy transition has gained special relevance in Latin America and the Caribbean (LAC), where growth in demand, accelerated urbanization, transport electrification, and national climate commitments drive the adoption of cleaner sources and systems [1–8]. Nonetheless, this process continues to put pressure on technological, financial, and institutional capacities, since energy represents a substantial share of greenhouse gas emissions and operating costs in productive sectors and essential services [9–14]. In response to these challenges, there has been growing interest in green energy solutions and innovative business models that align efficiency, competitiveness, and sustainability, enabled by digitalization, advanced analytics, and smart grids [15–21].

Within this framework, entrepreneurship and innovation have consolidated as key strategies to accelerate the transition, promoting practices that integrate distributed renewable generation, storage, active demand management, and new market schemes. Initiatives such as shared photovoltaics, community microgrids, living laboratories, flexibility platforms, and transfer between universities and industry show potential to scale solutions and mobilize investment in LAC's heterogeneous contexts [22–28]. However, their adoption faces structural barriers: fragmented or unstable regulatory frameworks, high financing costs for technology SMEs, information asymmetries, weaknesses in local supply chains, and sectoral resistance to transforming traditional practices [29–30].

Beyond environmental aspects, the region carries gaps in access, affordability, and supply quality, with disproportionate impacts on rural, peri-urban, and vulnerable communities. Inclusive solutions such as green microfinance, pay for performance tariffs, prosumer aggregation, pay for savings models, and innovative public procurement can reduce costs, improve resilience, and foster social participation in the transition [31–37]. Even so, the shortage of specialized human capital (R&D&I project management, economic regulation of networks, cybersecurity of energy systems, technoeconomic assessment) and limited training in sustainability and entrepreneurship remain critical obstacles to its sustained diffusion [38–44].

In this context, scientific research on green energy and entrepreneurship/innovation in LAC intensified during 2020 to 2024, yet its systematic mapping remains incipient. Analyzing its recent evolution is essential to identify dominant and emerging lines, leading actors and institutions, patterns of international collaboration (including extra-LAC links), and opportunities for alignment with public policy, financing, and technology transfer. This reading is key to guide decisions by governments, regulators, investment funds, technology-based firms, and universities.

Therefore, this study presents a bibliometric mapping of academic literature on green energy linked to entrepreneurship and innovation in LAC during 2020 to 2024. It identifies predominant themes, leading authors and institutions, and collaboration dynamics within and beyond the region, as well as emerging trends with potential impact on innovation and sustainable entrepreneurship ecosystems. The findings offer an integrated and decision-oriented view to drive the adoption and scaling of sustainable technologies and business models in LAC, in line with the region's environmental, economic, and social challenges.

II. METHODOLOGY

This study applies a PRISMA-guided bibliometric approach to map academic literature at the intersection of green energy and entrepreneurship or innovation in Latin America and the Caribbean for 2020 to 2024. The corpus was assembled from Scopus and Web of Science to provide a single, continuous view of identification, screening, eligibility, and inclusion consistent with the scope established in the introduction.

The search strategy combined two term blocks. The energy block included “green energy”, “renewable energy”, “clean energy”, “sustainable energy”, “energy transition”, hydrogen NEAR/3 (green OR renewable), “smart grid*”, microgrid*, “energy storag*”, solar, photovoltaic*, wind, bioenerg*, and geothermal*. The entrepreneurship and innovation block included entrepreneur*, startup* or start-up*, “new venture*”, “business model*”, “technology transfer”, “university–industry” or university NEAR/1 industr*, spin-off* or spinoff*, innovation*, “innovation ecosystem*”, incubator*, and accelerator*. Terms were applied exclusively to titles, abstracts, and keywords. In Scopus, the query was run in TITLE-ABS-KEY and limited to 2020 to 2024, document types Article and Review, and PUBSTAGE final. In Web of Science, the same logic was applied to TI, AB, and AK, limited to 2020 to 2024 and document types Article or Review, with exclusions for Early Access, Editorial Material, Correction, Data Paper, Retracted Publication, and Proceedings Paper. Regional relevance was ensured by requiring at least one author affiliation in a Latin American or Caribbean country, specifically Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Uruguay, Venezuela, Belize, Guyana, Suriname, Jamaica, Trinidad and Tobago, Bahamas, Barbados, Saint Lucia, Saint Vincent and the Grenadines, Grenada, Antigua and Barbuda, Dominica, and Saint Kitts and Nevis.

The identification step retrieved 481 records from Scopus and 443 from Web of Science, for a combined total of 924. After merging sources and removing duplicates by primary matching on DOI and secondary matching on title plus year, 570 unique records remained. Title, abstract, and keyword screening, together with the document-type and affiliation criteria, yielded a final set of 308 publications, consisting of 257 articles and 51 reviews. Figure 1 and Table 1 report counts at each stage and the main reasons for exclusion.

Screening ensured alignment with the study’s thematic intersection and the regional lens. Records were removed when they did not address both green energy and entrepreneurship or innovation, when their focus was incompatible with the LAC perspective, when they centered on fossil or conventional power without a green orientation, when they were purely conceptual without empirical, methodological, or bibliometric value for the intersection under study, or when no LAC institutional affiliation could be verified despite topical relevance.

Metadata curation and analytical steps: After screening, records were curated by standardizing affiliation and country fields and reconciling minor spelling and language variants. Author Keywords and Keywords Plus were merged into a single controlled vocabulary, assigning one uppercase label per idea after resolving inflections and near synonyms. The unified labels were organized into thematic axes that link technology and resources, grid integration and operation, sustainability and climate, policy and regulation, markets and finance, and entrepreneurship. On this curated base, Bibliometrix in RStudio was used to compute coauthorship, keyword cooccurrence, and citation patterns and to generate the word cloud, the three-field plot that connects keywords with countries and affiliations, and the thematic map. This common vocabulary aligns the evidence reported in Figs. 4–6 and enables tracking how ecosystem-oriented terms relate to the technological core across LAC.

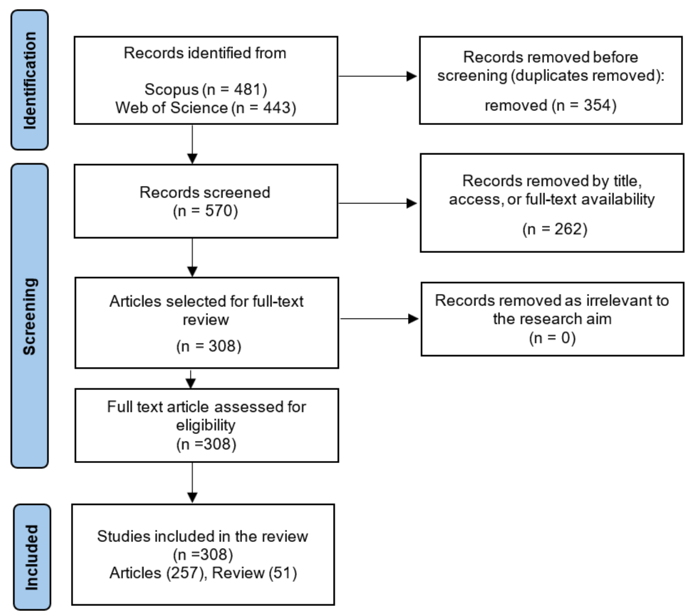

Figure 1. Flowchart describing the methodology used to select and filter documents on green energy and entrepreneurship/innovation in Latin America and the Caribbean (2020–2024).

TABLE 1. COMPONENTS OF THE BIBLIOMETRIC SEARCH STRATEGY

Component	Description	Terms/Operators
Search Fields	Specific areas searched within the database	Scopus and WoS: search in Title, Abstract, and Keywords (TITLE-ABS-KEY / TI–AB–AK).
Keyword Group 1	Energy-related concepts for capturing the green-energy domain	"green/renewable/clean/sustainable energy", "energy transition"; hydrogen NEAR/3 (green OR renewable); smart grid*, microgrid*, energy storag*; solar/photovoltaic*, wind, bioenerg*, geothermal*
Keyword Group 2	Innovation and entrepreneurship concepts linked to energy	entrepreneur*, startup* / "start-up*", "new venture*", "business model*", "technology transfer"; ("university NEAR/1 industr* OR "university–industry"); spin-off* / spinoff*, innovation*, "innovation ecosystem*", incubator*, accelerator*
Boolean Operators	Connectors and syntax used to combine concepts	Within blocks: OR; between blocks: AND; proximity: NEAR/n; phrases in quotes; truncation: *
Inclusion Criteria	Parameters for selecting relevant records	Years: 2020–2024; types: Article, Review; regional relevance: ≥1 author affiliation in a LAC country (Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Cuba, Dominican Republic, Ecuador, El Salvador, Guatemala, Haiti, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Puerto Rico, Uruguay, Venezuela, Belize, Guyana, Suriname, Jamaica, Trinidad and Tobago, Bahamas, Barbados, Saint Lucia, Saint Vincent and the Grenadines, Grenada, Antigua and Barbuda, Dominica, Saint Kitts and Nevis).
Exclusion Criteria	Documents not relevant to the study	Exclude early/advance versions (e.g., Early Access, Articles in Press), editorials, corrections/errata, data papers, retracted publications, and proceedings papers; remove records lacking the dual focus (energy AND entrepreneurship/innovation) or without a verifiable LAC affiliation.
Filters	Criteria for refining the search	Peer-reviewed final records only; search restricted to Title/Abstract/Keywords; retain only Article and Review.

III. ANALYSIS AND DISCUSSION

A. *Distribution of Scientific Production by Country.*

Figure 2 presents the distribution of publications by the corresponding author's country and distinguishes single-country publications (SCP) from multi-country publications (MCP). The configuration is clearly centered in Latin America and the Caribbean, with Brazil in a dominant position. Brazil accounts for 104 documents, which represents 36.7% of the total in this panel. Most Brazilian papers are domestic (85 SCP), while 19 involve international co-authorship, yielding an MCP rate of 18.3%. This combination of high volume and moderate internationalization is consistent with the presence of a large national research base that is able to generate output endogenously while selectively engaging in strategic collaborations that add complementary capabilities.

The second tier of production is led by Colombia and Mexico. Colombia contributes 37 documents (13.1%) and Mexico 32 (11.3%), both with very similar collaboration intensities near 19% MCP. These values suggest that the corresponding-author role in these countries remains largely anchored in national teams, although there is a meaningful and stable channel for cross-border work. The balance between SCP and MCP in Colombia and Mexico points to growing domestic capacities supported by partnerships that are activated when access to specialized infrastructure, methods, or datasets is required.

A different pattern emerges in countries with smaller volumes but high collaboration intensity. Ecuador has 14 documents and Chile 12, yet more than half of their output is internationally co-authored (57.1% and 58.3% MCP, respectively). This indicates an outward-looking strategy that leverages external networks to accelerate knowledge accumulation, visibility, and citation reach. Such profiles often correspond to groups that are positioned as agile partners in international consortia, where knowledge exchange and technology transfer flow bidirectionally. The challenge for these systems is to consolidate domestic pipelines of talent and funding so that internationalization translates into sustained local capability rather than dependence on exogenous leadership.

Argentina illustrates the opposite profile. With 11 documents, all of its output in this panel is domestic (100% SCP). An entirely national pattern may reflect a strong local research agenda, barriers to participation in international calls, or coordination costs that discourage cross-border work. From a system perspective, diversifying collaboration, particularly with regional neighbors that already show high MCP shares such as Chile and Ecuador could widen access to funding instruments, broaden methodological repertoires, and position Argentine teams more prominently in thematic clusters linked to green energy entrepreneurship.

Extra-regional partners play a visible bridging role. Spain contributes 11 documents with 63.6% MCP and Portugal 8 with 100% MCP, which underscores the relevance of Iberian institutions as preferred collaboration gateways for LAC teams. China and Italy, each with six documents and very high MCP shares (83.3% and 100% respectively), add focused but strategic links, often associated with specialized technologies or pilot deployments. The prominence of these partners in the corresponding-author perspective suggests that linguistic proximity, historical academic ties, and programmatic cooperation are important determinants of collaboration flows.

At the aggregate level, corresponding authors based in LAC account for approximately 77% of the documents in Figure 2, and the overall collaboration balance is 62.9% SCP versus 37.1% MCP. This mix is typical of a field that has reached a degree of domestic maturity while continuing to internationalize. Policy instruments that can shift the frontier include mobility schemes for early-career researchers, joint doctoral supervision, coordinated seed grants for multi-country projects, and interoperable data-sharing protocols that reduce transaction costs and accelerate replication. Strengthening triangular partnerships that connect an anchor country with high volume (Brazil) and a collaboration-intensive node (Chile or Ecuador) to an extra-regional bridge (Spain or Portugal) can maximize both scientific impact and the diffusion of entrepreneurial and innovation practices associated with green energy.

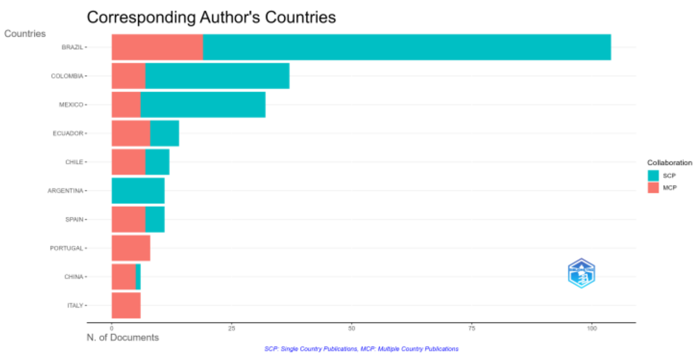

Figure 2: Distribution of Scientific Publications by Country

Figure 3 expands the view to the global distribution of scientific production. The center of gravity remains in Latin America and the Caribbean, with Brazil as the principal hotspot and Colombia, Mexico, Chile, and Ecuador forming the next ring. The Iberian Peninsula stands out as the main European interface, while China, Italy, and the United Kingdom appear as additional partners with more selective participation. This geography reveals a dual dynamic: a consolidated regional nucleus that sustains volume and a set of extra-regional bridges that amplify reach, credibility, and access to competitive funding. Countries that are currently more domestically oriented, such as Argentina, would benefit from embedding their groups in these bridge-mediated networks, whereas highly internationalized systems should invest in consolidating local infrastructure so that collaboration yields durable capability. Taken together, Figures 2 and 3 indicate that the field combines scale effects concentrated in a few LAC systems with collaboration architectures that increasingly connect the region to European and Asian partners, a configuration that can be leveraged to accelerate technological adoption, entrepreneurial scaling, and policy learning across the green-energy innovation ecosystem in Latin America and the Caribbean.

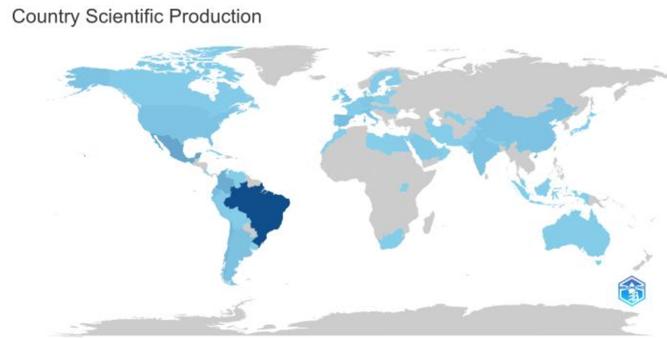

Figure 3: Country Scientific Production.

B. *Keywords and conceptual organization of the study.*

Figure 4 synthesizes the most salient terms in the set of articles and shows a field organized around a strong energy core. The figure was built from Author Keywords and Keywords Plus. Before plotting, we unified names and synonyms so that each idea appears under a single uppercase label, we aggregated their frequencies, and then we grouped the labels in line with the study objectives and the reviewers' notes.

The cloud reveals a clear energy center. RENEWABLE ENERGY anchors the vocabulary and connects with SOLAR ENERGY, BIOENERGY BIOMASS, WIND ENERGY, HYDROGEN, ENERGY STORAGE, and PHOTOVOLTAICS SOLAR PV. This technological block links to POWER SYSTEMS, SMART GRID, MICROGRIDS, and DISTRIBUTED GENERATION, which shows attention not only to clean technologies but also to how they operate and connect to the grid.

Alongside it sits a sustainability axis that brings together SUSTAINABILITY, CLIMATE AND EMISSIONS, and CIRCULAR ECONOMY LCA, supported by ENERGY EFFICIENCY and ENVIRONMENTAL IMPACT. This framework links technological progress to efficient resource use, life cycle thinking, and impact management, in line with regional goals on mitigation, equity, and affordability.

The elements that enable adoption are visible as well. POLICY AND REGULATION, MARKET DESIGN AND INSTRUMENTS, FINANCE AND INVESTMENT, and ENTREPRENEURSHIP AND STARTUPS act as a bridge from technology to market uptake. Their lower relative frequency suggests that the indexed literature places more emphasis on technology development, system integration, and policy framing, while incubation, acceleration, or university industry transfer appear less often in article indexing. This points to the value of broadening search terms in future work to capture that ecosystem more fully.

The map also highlights implementation routes that connect technology, markets, and policy. OPTIMIZATION MODELING CONTROL, together with design and reliability, underscores efficiency and robustness during deployment. E MOBILITY AND EVS and DISTRIBUTED GENERATION point to diffusion into decentralized and cross sector applications. The regional signal confirms the territorial anchoring of the set, with a critical mass of studies in Brazil and contributions from other Latin American countries.

Strategically, the keyword structure portrays a field moving forward in technological readiness and grid integration. HYDROGEN, ENERGY STORAGE, MICROGRIDS, and E MOBILITY AND EVS emerge as recurrent frontiers that call for regulatory adaptation and scalable business models. Strengthening the link between this energy core and entrepreneurship through research on replicable business models, risk sharing mechanisms, and innovation ecosystem design would help turn technical potential into adoption at scale across Latin America and the Caribbean.

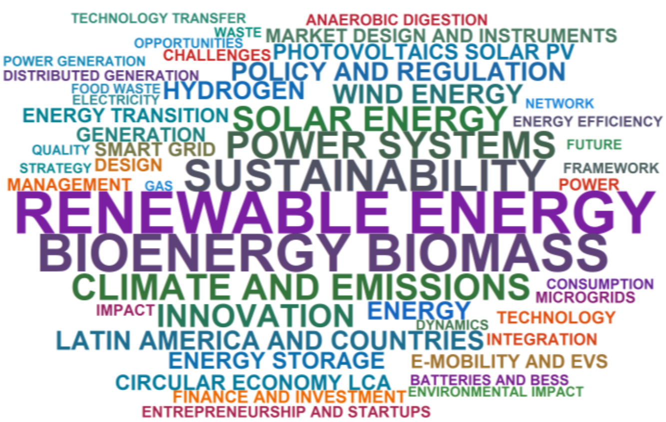

Figure 4. Figure 4. Canonized word cloud from Author Keywords and Keywords Plus.

C. Mapping Themes, Countries, and University Hubs

In continuity with the conceptual organization shown in Figure 4, Figure 5 presents a three-field plot that links merged keywords, authors' countries, and universities. The visualization brings together which topics concentrate recent output, where that work is done, and which institutions sustain it.

On the left column a clear energy core predominates. The most visible labels are RENEWABLE ENERGY, SOLAR ENERGY, BIOENERGY BIOMASS, HYDROGEN, and WIND ENERGY, together with POWER SYSTEMS and operational notions such as OPTIMIZATION MODELING CONTROL, DESIGN, MANAGEMENT, PERFORMANCE, and GENERATION. The presence of SUSTAINABILITY, SUSTAINABLE DEVELOPMENT, and CLIMATE CHANGE frames technological development within environmental and efficiency goals. Routes to grid integration and decentralized deployment are also visible through SYSTEMS and ENERGY TRANSITION.

The center of the diagram shows the territorial distribution. Brazil acts as the densest node and channels most flows between topics and publications. It is followed by Mexico and, with lower intensity, Colombia, Ecuador, and Chile. Bridges also appear to Spain, Portugal, the United States, the United Kingdom, Italy, Germany, India, and Argentina, with additional contributions from Saudi Arabia, Canada, Belgium, China, Denmark, Peru, and the Netherlands, reflecting selective collaborations that extend the regional reach.

The right column identifies the university hubs that sustain these fronts. Prominent institutions include the National Autonomous University of Mexico, the State University of Campinas, and the University of São Paulo, together with Brazilian poles such as the Federal University of Ceará, the Federal University of Rio de Janeiro, the Federal University of Paraná, the Federal University of Rio Grande do Sul, the Federal University of Santa Maria, and the Federal University of ABC. In the Southern Cone the University of Chile and the Technical University Federico Santa María stand out, while in the Andean region the University of Cuenca and the National University of Colombia appear. Among extra regional partners are the University of Jaén, the University of Minho, and Saveetha University. The pattern confirms a focused set of centers with critical mass that are natural partners for alliances, pilots, and transfer.

Read as a whole, the figure reinforces the message of Figure 4. The field is organized around an energy and systems core, framed by sustainability and climate, and supported by a concentrated group of universities that enable scale up. Identifying these countries and institutions offers practical guidance to prioritize consortia and to design support instruments that fit local capabilities.

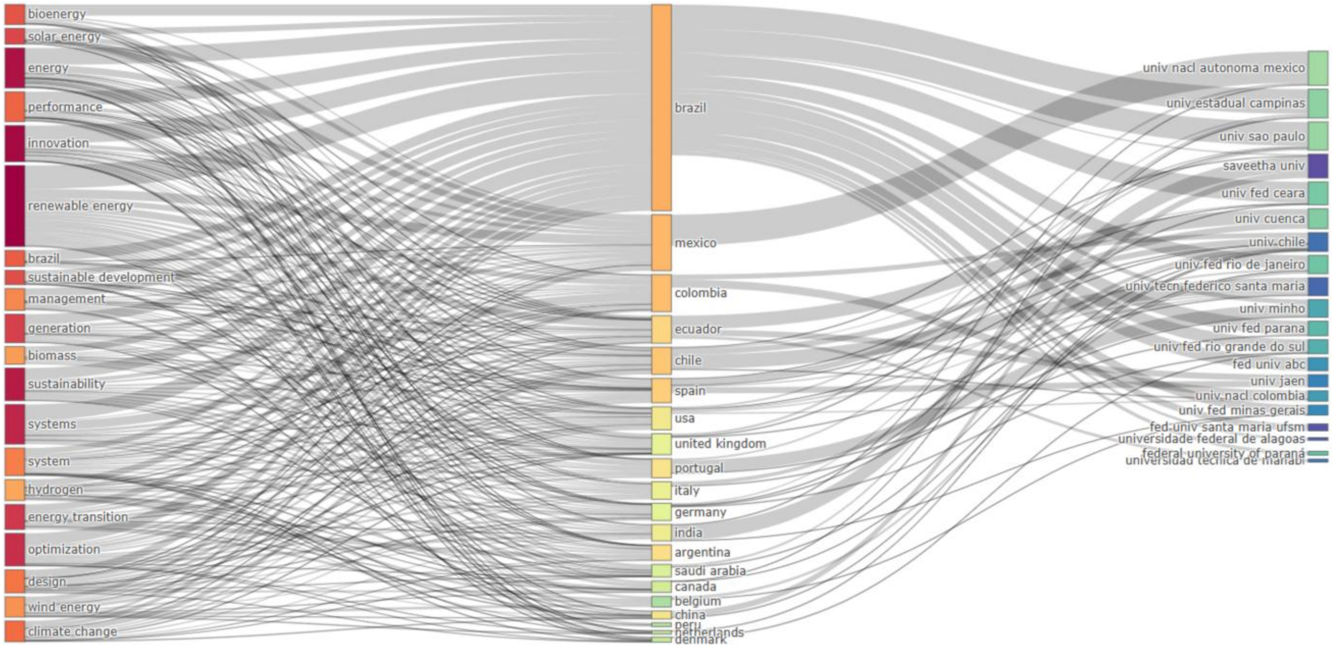

Figure 5: Three-field plot linking merged keywords, countries, and affiliations.

D. Thematic Map.

Figure 6 places the main themes on a thematic map where density indicates the degree of internal development and centrality indicates proximity to the main axis of the field. In line with the energy core observed in Figure 4, the upper right quadrant concentrates the motor themes: renewable energy, sustainable development, and clean energy appear tightly coupled. Their position reflects mature conceptual and methodological bases that support much of the discussion and confirm that the field is driven by decarbonization goals framed within sustainability agendas.

At the center of the map, business models and energy storage sit near the intersection of the axes. This placement suggests bridging functions between technical capability and market adoption rather than closed specialties. Storage acts as the technical hinge of flexible and distributed systems, while business models provide the economic logic to scale solutions. Their intermediate density indicates active research with room for consolidation through comparative evaluations, consistent techno-economic performance metrics, and clearer routes for commercialization and finance. This reading connects directly with Figure 5, where we identified the university hubs and countries that could accelerate that consolidation through pilot projects, regulatory instruments, and funding partnerships.

The lower right quadrant groups basic themes such as energy transition, energy sources, and solar energy. Their high centrality and lower density show them as references that structure a large share of studies and operate as cross-cutting anchors rather than specialized research fronts. This pattern is expected when a core narrative guides diverse applications, from grid integration to distributed generation and policy analysis.

The upper left quadrant hosts niche themes such as solar collector, project management, and project life. They show strong internal cohesion and weaker ties to the broader conversation, typical of specialized lines such as component-level optimization or lifecycle planning in specific implementation contexts. Connecting them more closely with adoption questions and with entrepreneurial mechanisms, for example project risk, performance contracts, or revenue schemes, would increase their influence beyond specific technical communities.

In the lower left quadrant, natural resources appear as an emerging or declining theme. Its peripheral position may indicate early-stage exploration of governance and availability, or a relative displacement by topics focused on immediate deployment. Linking this area to circular economy, materials criticality, and supply chain resilience would align resource debates with market formation and innovation strategy in Latin America and the Caribbean.

Taken together, the map portrays a field driven by renewable and sustainability agendas, where storage and business models act as connectors between technical maturity and adoption. Their movement toward the motor quadrant will likely depend on deeper evidence about value creation and risk sharing in real projects, a stronger interface with regulation and finance, and systematic learning from collaboration between university and industry and from entrepreneurial experimentation in the hubs identified in Figure 5.

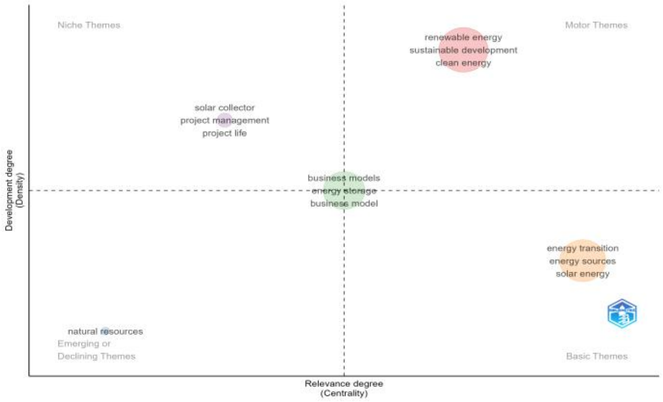

Figure 6: Strategic Diagram of Research Themes.

IV. CONCLUSIONS

This study offers a clear view of how green energy research and entrepreneurship are taking shape in Latin America and the Caribbean. Output is anchored in Brazil, with Mexico and Colombia as steady partners and frequent ties to Spain and Portugal. That mix of local critical mass and selective international bridges provides a sound base to scale collaboration without losing local roots.

Figure 4 confirms a strong energy center. Renewables, power systems, hydrogen, storage, and solar carry the conversation within a frame of sustainability, climate, and circular economy. Figure 6 adds a practical nuance. Storage and business models work as bridges between technical capacity and real use, while energy transition and energy sources act as basic anchors and more specialized lines remain as niche areas. Figure 5 brings the territorial and institutional layer, showing a focused set of university hubs that, if coordinated, can speed up common methods, replication of results, and transfer.

Looking ahead, the task is to tighten the link between technology and adoption. The signals related to policy, markets, finance, and entrepreneurship weigh less than the technological core, yet they are essential to turn pilots into broad uptake. The region will advance faster when storage and flexible operation travel with scalable business models that make value creation and risk sharing explicit, when the interface with regulators and financiers improves through pilot programs, instruments tied to measurable results, and open data, and when capacity building connects graduate training and short visits with collaboration between universities and firms.

There is also space to enrich the picture in future work. Extending the time window and adding full text in Spanish and Portuguese can test the stability of these patterns and reveal country specific threads that metadata alone may miss. Linking publications to funding and patent records would add a view of translation. For example, matching storage studies with national or multilateral grants could show which programs move projects from pilots to demonstration, while connecting clusters on hydrogen or microgrids with patent families and assignees could indicate where university and industry transfer is taking shape.

Taken together, the region already shows scale, recognizable hubs, and a path to wider use. Focusing on the bridge from technology to practice, especially through storage and sound business models supported by fit for purpose regulation and finance, can move green energy from demonstration to large scale diffusion and strengthen entrepreneurship and innovation across Latin America and the Caribbean.

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