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Competitive Advantages Of Ceará In The Production And Export Of Green Hydrogen To Europe: A Theoretical-Empirical Approach From The Resource-Based View Perspective

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Abstract:
Background: *This paper addresses the applicability of the Resource-Based View (RBV) in the domestic environment of the State of Ceará regarding green hydrogen (H_2V). It describes climate change, the effects of global warming, and the emergence of H_2V as a solution for the energy transition. Additionally, it presents the concepts of the RBV, applying them to the business environment of Ceará by identifying the resources, capabilities, and competitive advantages of the State in the production of H_2V.*
Materials and Methods: *This research adopted a qualitative approach to explore the concepts of the RBV in the H_2V value chain. The procedure used was a literature and documentary review, which involved consulting sources classified into three categories: (1) sources on global warming, energy transition, and H_2V; (2) sources on the RBV; and (3) sources that allowed the application of the RBV in the domestic environment of Ceará.*
Results*: The studies indicated the feasibility of strategic management benefiting from the RBV by fostering Ceará's competitive advantages as a supplier of H_2V to Europe.*
Conclusion*: The findings suggest that the RBV framework can enhance Ceará's positioning in the green hydrogen market, reinforcing its potential as a key player in the global energy transition.*
Keywords: *Resource-Based View; Business Environment; Global Warming; Competitive Advantages.*
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I. Introduction

Observing the socio-environmental context, natural disasters, and the effects of climate change in the 21st century, these circumstances have led the international community to become aware of the need for economic decarbonization, driving various energy policies to offset the use of fossil fuels.

The State of Ceará could not remain indifferent to this crucial moment. For this reason, it has also initiated an energy transition process to seize the global opportunities available and to contribute and participate as an energy provider in the planet's decarbonization.

The outlook for green hydrogen (H_2V) production is promising due to the state's existing resources and capabilities, which offer significant advantages. Regarding the planning and management of this transition in Ceará, high-level decision-makers have a variety of tools at their disposal, enabling them to conduct a more detailed analysis of the business environment.

The use of such methodologies supports strategic management and strengthens the energy-economic activity, directly and positively impacting the objectives and targets established in the H_2V value chain. One of these tools is the Resource-Based View (RBV), which guides managerial decisions and contributes to strategic diagnostics by anticipating, fostering, creating, and maintaining competitive advantages over competitors. As for the methodology adopted, the study employed a qualitative approach.

Regarding the research methods, it involved a bibliographic and documentary review based on national and international publications, reports from international organizations, scientific articles, books, and online sources. By consulting and consolidating these materials, it was possible to identify the key issues addressed in this study.

Thus, the general objective of this study is to analyze the contributions of a school of thought within business strategy—RBV—to the current scenario of H_2V in Ceará. As a result of this analysis, high-level decision-makers would be provided with a situational framework that enhances clarity in formulating business strategies

within organizational management. This, in turn, would contribute to the state's ability to create, develop, and consolidate competitive advantages over global competitors in producing and exporting this energy vector—the "fuel of the future"—to the European market. The specific objectives are: (i) to describe the circumstances of global warming, the energy transition, and the role of H_2V; (ii) to present the general concept of the RBV tool; and (iii) to demonstrate its feasibility in assessing Ceará's competitiveness in the production and export of H_2V to Europe.

This article is structured into four sections that provide an analysis of RBV applications in Ceará's current business environment. The first section, Introduction, presents the central theme of the study. The second section, Materials and Methods, describes the research approach, including data collection and analysis strategies. The third section, Theoretical Framework, explores global warming, the energy transition, and the role of H_2V as a key element in this transition; it also examines the general concepts of RBV strategy and its applicability in the H_2V value chain. Finally, the Conclusion section summarizes the study's key findings, highlighting the advantages of applying RBV concepts in decision-making processes related to the production and export of H_2V to Europe.

II. Material And Methods

The approach adopted in this research was qualitative in nature, as the primary objective was to apply RBV concepts to the current scenario of green hydrogen (H_2V) production and export from Ceará to Europe. This approach is widely recognized in the scientific community for its ability to provide contextual analyses, allowing an assessment of the internal environment in Ceará within the present context of the energy transition.

Qualitative research focuses on the interpretation and understanding of complex phenomena, making it essential in fields that involve resources, capabilities, and skills in energy vector production, where internal and external variables are broad and dynamic.

González (2020) highlights that in qualitative research, the epistemological position is occupied by researchers, who assume cognitive commitments to ensure the quality of the study. The research procedure adopted was a literature review and a documentary analysis, both of which are essential for scientific knowledge construction, as they enable a critical and integrated analysis of existing information on a given topic.

According to Lakatos and Marconi (2017), a bibliographic review contributes to a deeper understanding of the research subject while promoting the consolidation of well-founded approaches. For this review, research sources were selected and classified into three main categories: 1. Sources on global warming, energy transition, and H_2V in Ceará; 2. Literature sources detailing RBV concepts; 3. Sources that characterize the applicability of RBV in the current context of H_2V production in Ceará and its export to Europe the classification of these sources enabled a more precise and contextualized analysis, allowing the development of a robust discussion on the applicability of RBV in Ceará's current scenario regarding H_2V production and export to Europe.

The literature and documentary review were conducted through the examination of national and international publications, reports from international organizations, scientific articles, books, and online sources, ensuring a broad scope that reflects the most relevant and up-to-date contributions in strategic and energy management.

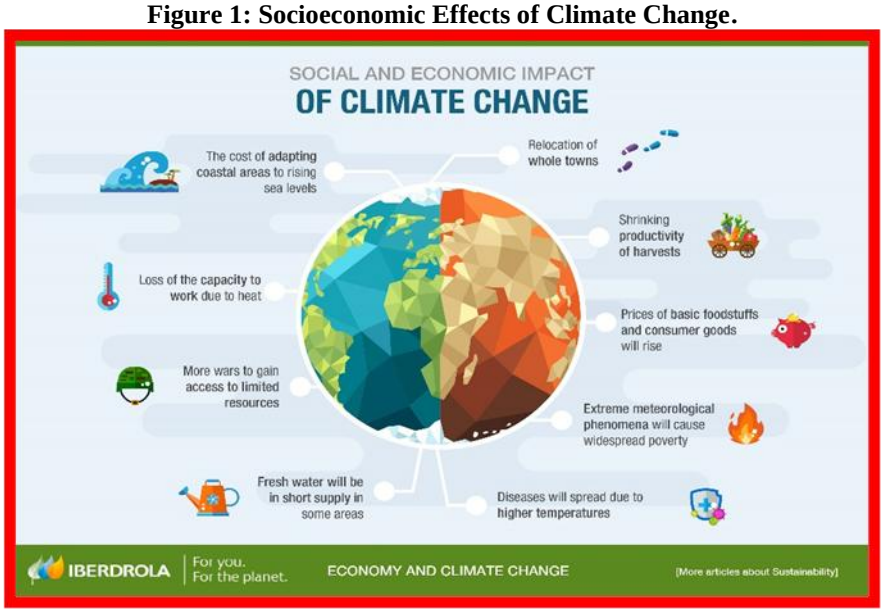
III. Literature Review

This theoretical framework was structured into three subtopics. The first clarifies global warming, the energy transition, and the role of green hydrogen (H_2V) in the energy transition in response to the effects of climate change. The second presents the general concept of the Resource-Based View (RBV) by introducing the key ideas of prominent scholars in the field. The third explores the contributions and applicability of RBV concepts in the current context of the State of Ceará, considering the situations and initiatives implemented to support H_2V production and export to Europe.

Global Warming, the Global Energy Transition, and Green Hydrogen (H_2V)

Flooding in coastal areas due to rising sea levels, reduced work capacity and the spread of diseases caused by high temperatures, difficulties in accessing potable water sources, decreased agricultural production due to adverse climatic events, and rising food prices are common examples of the effects of climate change in various cities. These phenomena result in tragic human losses and severe socio-economic impacts (Figure 1).

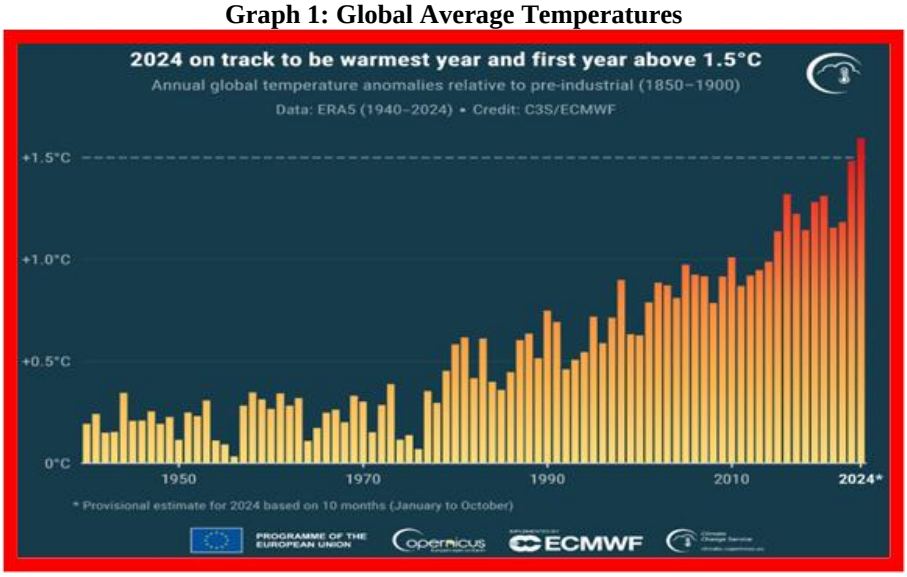
Figure 1: Socioeconomic Effects of Climate Change.



Source: Iberdrola[1].

Other climate events have become increasingly frequent, such as widespread droughts, glacier melting, and rising global average temperatures. These occurrences had already been highlighted in the 2007 Intergovernmental Panel on Climate Change (IPCC) Report (Holanda, 2016). Recently, 2024 made history as the hottest year since the pre-industrial period (1850–1900). Contrary to the goals of the Paris Agreement, the global average air temperature exceeded 1.5°C above this historical benchmark for the first time (Graph 1). This threshold, already considered critical by the IPCC, had been projected to be reached only by the end of this decade (Martinez, & Christofoletti, 2024).

Graph 1: Global Average Temperatures



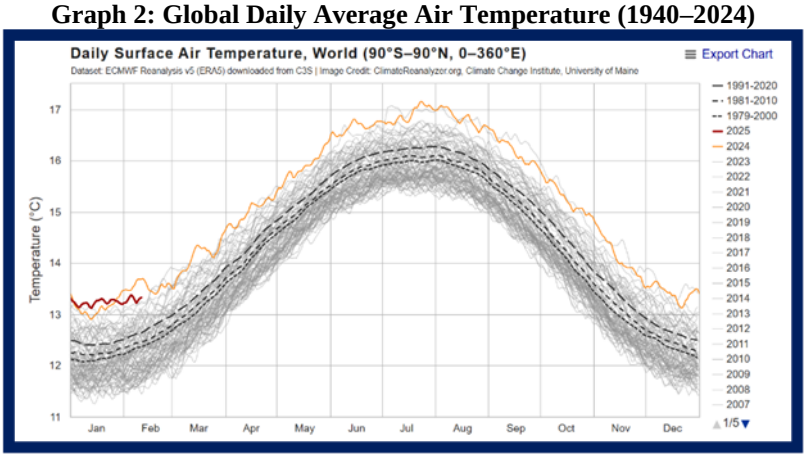
Source: Observatório Climático da Comissão Europeia *Copernicus*[2].

Another alarming piece of data is presented in Graph 2. The orange line represents 2024 as the hottest year on record, surpassing the previous records set in 2023 (gray) and significantly exceeding the historical averages for the periods 1979–2000, 1981–2010, and 1991–2020. This continuous temperature increase over decades clearly indicates ongoing global warming (Martinez, & Christofoletti, 2024).

[1] Iberdrola. How is climate change affecting the economy and society? Disponível em: https://www.iberdrola.com/sustainability/impacts-of-climate-change. Acesso em 17 fev. 2025.

[2] Copernicus: Second-warmest November globally confirms expectation for 2024 as warmest year | Copernicus Acesso em 17 fev. 2025.

Graph 2: Global Daily Average Air Temperature (1940–2024)



Source: Climate Reanalyzer (Climate Change Institute, University of Maine).

In this challenging climatic and environmental context, green hydrogen (H_2V)—produced from renewable energy sources—emerges as an alternative solution to offset the use of fossil fuels. It is currently regarded as the cornerstone of the global energy transition, playing a crucial role in the energy transition strategies of multiple countries, particularly by offering a viable alternative for highly carbon-intensive sectors (MME, 2023).

This perspective aligns with the United Nations High-Level Political Forum Policy Report[3], which highlights H_2V as a key solution for hard-to-decarbonize sectors (Santos, & Gandara, 2022). In response, the Government of the State of Ceará, in close cooperation, coordination, and integration with the Federation of Industries of the State of Ceará (FIEC), higher education institutions, and national and international corporate partners, has committed to developing the H_2V supply chain within the state.

This initiative is centered around the Pecém Industrial and Port Complex (CIPP), aiming to position Ceará as a global player in the worldwide supply chain of this energy vector, contributing effectively to the global energy transition. Regarding strategic planning and high-level decision-making, which analytical tool could be useful in mapping Ceará's potential competitive advantages against global competitors? One viable solution available to policymakers is the Resource-Based View (RBV)

General Conception of the Resource-Based View (RBV)

Michael Eugene Porter and other scholars in the field of strategic planning have developed various models and analytical frameworks for formulating strategies concerning strengths and weaknesses, as well as environmental opportunities and threats, to understand the sources of competitive advantage (Porter, 1980, apud Kretzer, & Menezes, 2006).

However, this article does not focus entirely on the classical and well-established SWOT (Strengths, Weaknesses, Opportunities, Threats) matrix approach, a technique used by organizations to identify and analyze the strengths and weaknesses (internal environment) and the opportunities and threats (external environment) of a business plan (Kuazaqui et al., 2018).

Specifically, this study will be based solely on the internal environment of organizations, aiming to describe how existing variables could foster, create, develop, and consolidate the much sought-after competitive advantages over competitors. The studies highlighted only the internal and controllable variables that could provide advantages to the system, strengthening them to overcome threats and seize emerging opportunities (ESG, 2023).

This is the essence of the RBV, whose origins stem from the valuable contributions of economist Edith Penrose, developed in The Theory of the Growth of the Firm (1959). According to Penrose, companies, driven by their skills and capabilities, generate and sustain competitive advantages by developing internal organizational resources capable of yielding superior profitability (apud Kretzer, & Menezes, 2006; Guedes Laimer, & Rossato Laimer, 2009; Augusto, 2017).

These principles suggest that a company's performance depends on resources built through internal accumulation, achieved by creating, maintaining, and renewing competitive advantages associated with internal attributes (Foss, 1993, apud Kretzer, & Menezes, 2006).

Under these circumstances, organizations would not be analyzed based on their products but rather on their resources—anything that could be considered a strength or weakness of a given company (Wernerfelt, 1984, apud Vilela & Jhunior, 2018). For Mintzberg et al. (2020), the RBV focuses on the origin, development, and

[3] Climate Reanalyzer. Disponível em: https://climatereanalyzer.org/clim/t2_daily/?dm_id=world. Acesso em 17. Fev. 2025.

sustainability of organizational capabilities—an inside-out perspective that turns inward to investigate the strengths and weaknesses of an organization's resource positioning. Thus, strategic resources are considered essential for both defining strategy and establishing competitive advantage, forming the core premise of the RBV (Gohr et al., 2011).

Therefore, RBV is based on competencies, capabilities, and skills as the foundation of productive and organizational knowledge, enabling managers to understand the conditions under which resources generate competitive advantages, which are crucial for a company's strategic vision (Barney, 1991, apud Kretzer, & Menezes, 2006).

Through RBV concepts, organizations would be better positioned to perform activities by acquiring and sustaining competitive advantages through the development of internal resources that, in one way or another, surpass those of competitors (Augusto, 2017; Gohr et al., 2011).

With this thorough analysis, it would be possible to capitalize on opportunities through strengths, improve weaknesses, monitor threats by leveraging strengths, and eliminate weaknesses in response to environmental threats (Martignago, 2011). The importance of RBV spans multiple fields of knowledge and is widely recognized as one of the most significant and powerful theories for describing, explaining, and predicting organizational relationships (Barney, Ketchen, & Wright, 2011, apud Vilela, & Jhunior, 2018).

For clarification, in this article, the internal environment encompasses everything within an organization's boundaries, referring to the resources, capabilities, and competencies available to the company or those it could potentially develop (Martignago, 2011).

This understanding allows the organization to define and implement strategies in its business model (Guedes Laimer & Rossato Laimer, 2009).

Types of Internal Resources in the Resource-Based View (RBV)

Barney (1991, apud Guedes Laimer & Rossato Laimer, 2009; Augusto, 2017) defines resources as assets, capabilities, organizational processes, information, and knowledge controlled by a firm, which enable it to create and execute strategies that enhance efficiency and effectiveness.

Examples described by Barney (1991) include physical capital resources (technology, factories, equipment, geographical location, and access to raw materials), human capital resources (training, experience, intelligence, and relationships), and organizational capital resources (formal systems and structures, as well as informal relationships within groups). From the perspectives of Penrose (1959) and Barney (1991), competitive advantage is linked to the fact that companies possess a set of distinctive resources that meet the demands of the markets in which they operate (Augusto, 2017).

These resources can be tangible or intangible, a widely recognized distinction in strategic management literature (Gohr et al., 2011). By identifying these differences, managers and decision-makers can leverage them to select and implement strategies, thereby establishing sources of capabilities that ensure competitive advantage (Martignago, 2011).

Conceptually, tangible resources are visible and quantifiable, such as machinery, equipment, facilities, and financial resources. In contrast, intangible resources are more challenging to identify and quantify; they are not tangible or concrete and are embedded within the organization, making them difficult to comprehend and imitate—examples include trust, organizational knowledge, and reputation (Martignago, 2011).

For a clearer understanding, Hitt, Ireland, & Hoskisson (2003) proposed a classification of tangible and intangible resources, as outlined in Table 1.

Table 1: Classification of Resources and Capabilities

Tangibles	Financial	Availability of financial resources, ability to manage internal funds, raise external capital, and retain earnings.
	Physical	Geographical location of factories, existence of machines and equipment, access to raw materials, and distribution channels.
	Technological	Assets that generate products and services backed by patents, trademark registration, and copyrights; R&D and S&T.
	Organizational	Formal systems of planning, command, and control; integrated administration, information, and communication systems; relationship with external audiences and teamwork.
Intangibles	Human	Training of managers and employees, experience, intelligence, relationships, knowledge, and talents inherent to the company.
	Innovative	Favorable environment for new ideas, R&D capacity, and ability for innovation and organizational changes.
	Reputational	Ability to develop and enhance reputation as a provider of products and services, an attractive employer, and an entity with corporate social responsibility.

Source: Hitt, Ireland, & Hoskisson, 2003, apud Guedes Laimer, & Rossato Laimer, 2009.

However, resources alone would be insufficient to generate a competitive advantage. An organization, for instance, may possess a substantial amount of capital that enables it to enter the international market. However,

these resources, when combined with others such as machinery and reputation, do not necessarily guarantee the successful implementation of its strategy (Martignago, 2011).

In this context, resources are not merely a set of capabilities but rather a collection of internal forces that interact with and influence one another. Therefore, to achieve a competitive advantage, it is essential to have resources capable of performing tasks in an integrated manner, employing them dynamically and systematically to accomplish specific objectives, thereby creating a complex interaction between tangible and intangible assets (Martignago, 2011).

This is the premise of the Resource-Based View (RBV): the coordination, integration, and interaction of an organization's internal resources to identify, generate, and sustain competitive advantages while simultaneously creating business growth opportunities and guiding strategic formulation.

Identification of Core Competency and Competitive Advantage

As previously discussed, internal resources constitute valuable sources of a company's capabilities, contributing to the creation and maintenance of competitive advantages. Hence, it is crucial to understand another significant aspect of RBV: core competencies as a source of competitive advantages, as they generate value for customers (Martignago, 2011).

According to Hamel and Prahalad (1999, as cited in Martignago, 2011), the concept of core competency refers to a set of skills and technologies that enables a company to deliver a specific benefit to customers. These authors argue that a company possesses a core competency when: a. It comprises a set of skills and technologies rather than a single isolated skill or technology, as a competency represents the accumulated learning from all organizational skill sets; b. It generates perceived customer value by leveraging its core competencies to meet high competitive standards. Value is defined by the characteristics and performance attributes of goods and services that customers are willing to pay for; c. It possesses a competitively unique capability that differentiates it from competitors; and d. It has the capacity for expansion by generating a range of new products and services from its core competency.

From a strategic perspective, Hitt, Ireland, and Hoskisson (2003, as cited in Martignago, 2011) suggest that a core competency should be the combination of resources and capabilities that are: a. Valuable, allowing the firm to capitalize on opportunities and/or neutralize threats in the external environment; b. Rare, meaning they are uncommon and possessed by only a few competitors; c. Imperfectly imitable, meaning the resource must not only be valuable and rare but also difficult to replicate; and d. Non-substitutable, meaning there are no equivalent alternatives within the industry.

A resource may be rare and inimitable, but it will not be strategic if competitors can find a substitute for it. Based on these considerations, Barney (1991, as cited in Guedes Laimer & Rossato Laimer, 2009) developed a theoretical model comprising fundamental criteria for identifying resources that generate competitive advantages (Table 2), allowing firms to determine whether a specific resource constitutes a source of competitive advantage.

Table 2: Criteria for Identifying Sustainable Competitive Advantage

Valuable?	Rare?	Difficult to Imitate?	Non-Substitutable?	Competitive Implications	Performance
No	No	No	No	Competitive Disadvantage	Below Normal
Yes	No	No	Yes ou No	Competitive Parity	Normal
Yes	Yes	No	Yes ou No	Temporary Competitive Advantage	Above Normal
Yes	Yes	Yes	Yes	Sustainable Competitive Advantage	Above Normal

Source: Adapted from Barney (1991, as cited in Guedes Laimer, & Rossato Laimer, 2009).

It is emphasized that merely possessing resources with such characteristics (Table 2) would not, by itself, constitute an advantage. Instead, the ability to integrate and develop them, thereby making them advantageous, is crucial (Barney, 1991, as cited in Vilela & Jhunior, 2018).

In summary, competitive advantage would be based on the company's strategic ability to coordinate human effort and effectively assess the positioning of its resources in terms of strengths and weaknesses, implementing strategies to leverage existing organizational assets (Kretzer, & Menezes, 2006).

Thus, it is partially concluded that high-level managers are responsible for conducting a detailed analysis of the company's internal environment, aligning the present and future situation with Tables 1 and 2. Based on this assessment, they should identify strengths and opportunities for improvement to continuously enhance their competitive advantages in relation to competitors.

Scenarios and Initiatives in Ceará for the Production and Export of Green Hydrogen (H2V) to Europe

Given that this sector is strategic for Ceará's economy due to its potential to drive socioeconomic development, improve the training of specialized human resources, foster research and the development of new technologies, and even contribute to the global energy transition, employing the Resource-Based View (RBV) framework becomes essential as a strategic planning tool.

By analyzing Table 1 alongside relevant facts and developments in Ceará, it is evident that the state has accumulated resources and capabilities that could contribute to generating and sustaining competitive advantages, in accordance with the principles established by Barney (1991).

a. Analysis of Tangible Resources and Capabilities in the State of Ceará

1) Financial Resources

The H2V production project has attracted multi-billion-dollar investments, demonstrating the state's ability to secure and manage large-scale financial resources. Some notable examples include: - The State Government has invested in enhancing the use of the Pecém Industrial and Port Complex (CIPP) as a strategy for economic development, while also strengthening its logistical and port infrastructure (IPECE, 2022). - The Pecém Port (CIPP) has projected R$ 2.2 billion in investments by 2028, aiming to modernize the hub, including services such as electricity, water reuse, and other infrastructure-related segments. The World Bank and the Ministry of Development, Industry, and Trade have financed the hub's infrastructure with a US$ 100 million investment (Vasileva, 2023). - In 2024, a preliminary contract worth US$ 3 billion was formalized with the French company Voltalia for the establishment of an H2V and green ammonia production unit at CIPP. In the same year, a R$ 9 billion preliminary contract was signed with the Norwegian company Fuella AS (a developer and operator of H2V plants) for the installation of a facility in the Export Processing Zone of CIPP.

2) Physical Resources

A key natural advantage of Ceará is its wind regime (up to 36 km/h, considered excellent) and an average annual solar radiation of 5.5 kWh/m² per day, which enables the cost-effective production of wind and solar photovoltaic energy (renewable energies) compared to other global producers. In Ceará, solar and wind energy—both of which can be generated year-round—are highly complementary, as their peak production occurs at alternating times throughout the day (FIEC, 2024). These geoeconomic conditions are enhanced by the Weibull factor (Silva et al., 2020; ADECE, 2019) concerning wind patterns, as well as the state's location within the solar belt, its low latitudes, and proximity to the Equator (Barbosa & Gomes, 2024a). Situated in the Northeastern Salient and bordering the Atlantic Ocean (maritime influence), CIPP occupies a strategically privileged geographic position for the future export of H2V to Europe (Barbosa & Gomes, 2024a). The establishment of the hub at CIPP in 2021 (Bezerra, 2023) integrated an industrial-port complex, optimizing costs and time—an essential factor in the hydrogen economy—while aligning with a global trend of developing renewable energy production sites near strategic ports (Oliveira, 2022). Another critical factor is access to distribution channels, which, when well-structured, facilitate product availability in the market and enhance customer retention rates (Arbache et al., 2006, as cited in Barbosa & Gomes, 2025). In this regard, the Ceará state government and the Netherlands established the Pecém-Rotterdam maritime corridor in 2023, creating a trade route for this energy vector's future commercialization in the European continent (Vasileva, 2023). According to the Port of Rotterdam (2023), this partnership aims to strengthen bilateral cooperation by promoting initiatives in port development, logistics, inland connectivity, and energy-related projects, including offshore wind energy and H2V production (Barbosa & Gomes, 2025).

3) Technological Resources

In terms of technological assets, one of the key milestones in research and development was the 2024 launch of the Renewable Energy Research and Innovation Network (Rede VERDES). This initiative aims to foster collaborative and multidisciplinary research and comprises over 100 researchers from 26 research units within 14 higher education institutions (Barbosa & Gomes, 2024b). Another example of Ceará's technological capacity is the Jurandir Picanço Center of Excellence for Energy Transition, reaffirming the state's commitment to incorporating technological assets in support of the energy transition (Barbosa & Gomes, 2024b).

4) Organizational Resources

Ceará has consolidated excellent organizational resources and capabilities, characterized by inter-institutional collaborations involving key actors from various sectors of society. In 2023, the Pacto pelo Pecém initiative was resumed. This program brings together political, industrial, academic, civil society, and environmental sectors to promote multi-sector governance and socio-environmental sustainability. A key pillar of the Pacto pelo Pecém is the H2V hub as a clean energy production center (Barbosa & Gomes, 2024b). Additionally, through the Ceará Industry Federation (FIEC), the state was selected by the UN Global Compact as

the headquarters for the Sustainable Development Goals (SDG) hub. This initiative seeks to mobilize companies and institutions to engage in sustainable, inclusive, and equitable actions focused on renewable energy, education, health, and labor, among other areas. Another significant step was the 2022 implementation of the Environmental, Social, and Corporate Governance (ESG) Program, the first of its kind in Brazil's industrial sector. This initiative aims to guide industries in sustainability projects, incorporate best environmental preservation practices, and mitigate environmental impacts in production processes (Barbosa & Gomes, 2024b). Audited by Bureau Veritas (a certification organization founded in 1828 in Belgium, now headquartered in France), the program enhances competitiveness and credibility among global stakeholders, ensuring greater security in negotiations and investment attraction within the hydrogen economy. ####

b. Analysis of Intangible Resources and Capabilities in the State of Ceará

1) Human Resources

In general terms, young people in Ceará hold a privileged position in national education rankings. In the 2023 Basic Education Development Index, Ceará achieved the best results in Brazil for primary education within the public-school network. At the state level, it ranked third in Brazil for both traditional secondary education and integrated technical secondary education (Falcão, 2024). Thus, the high educational level of Ceará's human resources translates into their training and qualification, preparing them to work in the complex and demanding energy sector (H_2V value chain). In 2024, the Ceará State Government launched the H-TEC State Project for Qualification and Strengthening of the Renewable Energy Production Chain. This initiative supports professional training in partnership with the Ceará Science and Technology Support Foundation, the National Service for Industrial Learning (SENAI/FIEC), the Federal University of Ceará (UFC), the State University of Ceará, and the Federal Institute of Ceará (IFCE) (Barbosa & Gomes, 2024b). SENAI itself has prioritized training human resources in renewable energy, demonstrating the industrial sector's commitment to ensuring the necessary qualifications in the energy technology field (Table 3).

Table 3: Training Programs Conducted by SENAI.

Course/Education/Qualification	Workload
Wind Energy Technology	32 h/class
Wind Turbine Blade Repair	160 h/class
Hydrogen, Energy (Wind and Solar) and Workplace Safety	360 h/class
Photovoltaic System Assembly	40 h/class
Photovoltaic System Commissioning	40 h/class
Photovoltaic System Assembly	40 h/class
Safety Applied to Hydrogen Storage and Distribution	60 h/class

Source: Barbosa, & Gomes (2024b, p. 26).

The UFC stands out in scientific and technical training, providing faculty members and researchers in areas related to H2V technology, as well as laboratories for research and education (UFC, 2021). The IFCE is also specializing in the training of human resources focused on renewable energies. The institute has a campus within the CIPP area and has launched a specialization course (lato sensu postgraduate level) with the support of the German Cooperation Agency (GIZ), aimed at developing solutions in the production, distribution, and application chain of H2V (Barbosa, & Gomes, 2024b).

Finally, the Euvaldo Lodi Institute (IEL) has been specializing professionals in the renewable energy sector, addressing current market demands. Examples include the MBA in Renewable Energy Management, offered in partnership with the Farias Brito University Center (Barbosa & Gomes, 2024b).

2) Innovators

Building on the legacy of R&D and innovation efforts from the aforementioned institutions (H-TEC, SENAI, UFC, IFCE, and IEL), additional initiatives have been strengthening the innovation landscape in the state of Ceará. In 2024, the "FIEC Innovation Index of the States" was published, enabling high-level decision-makers to design and implement public policies to foster an innovative ecosystem, with participation from business leaders, universities, public entities, and the third sector (FIEC, 2024b, p. 14).

To illustrate, in the overall ranking and for the second consecutive year, Ceará was the most innovative state in the Northeast region, securing 8th place nationally. This index is expected to contribute to a more favorable educational environment for new ideas, enhancing the state's capacity for innovation and organizational transformation.

3) Reputational Aspects

Regarding reputational aspects, Ceará has demonstrated institutional capacity to develop and drive initiatives that enhance credibility in H_2V production. In addition to the ESG Program (social and environmental responsibility), the UN Global Compact initiative has enabled the state to efficiently leverage its renewable energy

resources, consolidating multiple agreements and memoranda of understanding with multinational companies through paradiplomacy efforts (Barbosa, & Gomes, 2024a).

For instance, a bilateral agreement was established between Pecém and Rotterdam, which is recognized as the largest seaport in Europe. This joint venture yields greater benefits for production institutions, given that Rotterdam is already well positioned in the European market as a port complex integrating H2V production and consumption, distribution infrastructure for other European countries (pipelines extending to Belgium and Germany), an import terminal, and electrolyzers (FKA, 2022; Oliveira, 2022 apud Barbosa & Gomes, 2024a).

"Since the launch of the hub, more than thirty-five MoUs have been signed with national and international institutions interested in developing projects in the state (Bezerra, 2023, p. 11)."

Within the framework of paradiplomacy, several countries have already signed agreements with the state (Table 4), demonstrating interest in Ceará as a provider of energy solutions. This interest is also based on the fact that the importing country can benefit from the existing electrical grid in Ceará, given that 70% of the hydrogen production cost is related to energy costs (McKinsey, 2021, apud Barbosa & Gomes, 2024a).

Table 4: Confirmed Projects and Investments in the Port of Pecém (H_2V)

País	Empresa	Valores previstos (US$) [1]	Local de investimento
Austrália	Fortescue Future Industries	6 bilhões	Porto do Pecém, Ceará
Holanda	Transhydrogen Alliance	2 bilhões	Porto do Pecém, Ceará
Austrália	Enegix Energy	5,4 bilhões	Porto do Pecém, Ceará
França	Qair	6,95 bilhões	Porto do Pecém, Ceará
Portugal	EDP do Brasil	8 milhões	Porto do Pecém, Ceará
França	Engie	-	Porto do Pecém, Ceará
Espanha	Neoenergia	-	Porto do Pecém, Ceará
Alemanha	White Martins	-	Porto do Pecém, Ceará
Alemanha	Linde	-	Porto do Pecém, Ceará
França	TotalEnergies	-	Porto do Pecém, Ceará
Brasil	Eneva	-	Porto do Pecém, Ceará
Brasil	Diferencial Energia	-	Porto do Pecém, Ceará
Alemanha	Hytron	-	Porto do Pecém, Ceará
Brasil	H2helium Energia	-	Porto do Pecém, Ceará

Source: Oliveira, 2022 apud Barbosa, & Gomes, 2024a.

Thus, Table 4 highlights Ceará's credibility in the international market as a key global player in H2V, reinforcing its reputation as a potential supplier of H_2V to the European market through the initiatives and actions already undertaken.

In the context of the energy transition, a notable reputational advantage is the interinstitutional integration (internal environment) demonstrated by the state. This aligns with the International Energy Agency (IEA) report, which states that developing low-carbon hydrogen production presents a challenge requiring simultaneous and coordinated efforts across multiple fronts. According to the IEA, this is the only way to achieve the engagement of all stakeholders, including governments, industry, research and innovation agencies, financial services, trade unions, and civil society (IEA, 2021 apud Barbosa & Gomes, 2024a).

As a synthesis of the studies presented, in terms of Ceará's tangible and intangible resources and capabilities (referenced in Table 1) and substantiated by the literature of Penrose, Barney, among others, Table 5 was developed. This table consolidates the actions and initiatives undertaken in the state that could potentially contribute to generating and sustaining Ceará's competitive advantages in H2V production and its subsequent exportation to Europe.

Table 5: Classification of Resources and Capabilities

Tangibles	**Financial**	Availability of the company's monetary resources, ability to manage internal funds, raise external capital, and retain earnings.	• High national and foreign investments in the state, amounting to billions of dollars.
	Physical	Geographic location of factories, existence of machinery and equipment; access to raw materials and the company's distribution channels.	• Physiography (position, climate, latitude, maritime influence, and wind regime); • Renewable energy generation (solar and wind); and • Green Hydrogen Hub at CIPP.

Intangibles	**Technological**	Assets that generate products and services supported by patents, trademark registration, and copyrights; R&D and S&T.	● VERDES Network; and ● Jurandir Picanço Center of Excellence.
	Organizational	Systems of formal planning, command, and control; integrated information and communication management systems; relationship with the external public, teamwork.	● Pacto pelo Pecém; ● UN Global Compact; and ● ESG-FIEC Seal.
	Human	Training of managers and employees, experience, intelligence, relationships, knowledge, and talents inherent to the company.	● H-TEC Qualification; ● Training of specialized human resources (SENAI, UFC, IFCE, and IEL).
	Innovative	Environment conducive to new ideas, R&D capability, innovation capacity, and organizational changes.	● H-TEC Qualification; ● VERDES Network; and ● FIEC Innovation Index of the States.
	Reputational	The company's ability to develop and enhance its reputation as a supplier of products and services, an attractive employer, and an entity with corporate social responsibility.	● ODS Hub (UN Global Compact); ● ESG-FIEC Seal; ● Paradiplomacy; ● Pecém-Rotterdam Joint Venture; and ● Establishment of partnerships, alliances, agreements, and MoUs.

Source: Hitt, Ireland, & Hoskisson, 2003, apud Guedes Laimer, & Rossato Laimer, 2009.

Following the same line of reasoning, Table 2, established based on Barney's theoretical model (1991), was analyzed. In the case of Ceará, considering the international context of economic decarbonization, the global energy transition, the H2V value chain, and the studies conducted thus far, the following strategic inferences can be made:

a. Valuable

H2V, given the investments in the development of its production chain, is considered a valuable product and has driven numerous energy policies worldwide. "Estimates from the Hydrogen Council indicate that this market is expected to reach USD 2.5 trillion globally by 2050, accounting for approximately 20% of the world's total energy demand" (Martins, 2021, p. 31).

It is valuable because it prioritizes the use of renewable energies. It is valuable because it serves as a compensatory alternative to fossil fuels (oil, gas, and coal), which are responsible for greenhouse gas emissions (air and ocean warming). For this reason, producing it in Ceará represents an opportunity to benefit from the prospects offered by the global energy transition (external environment). ###

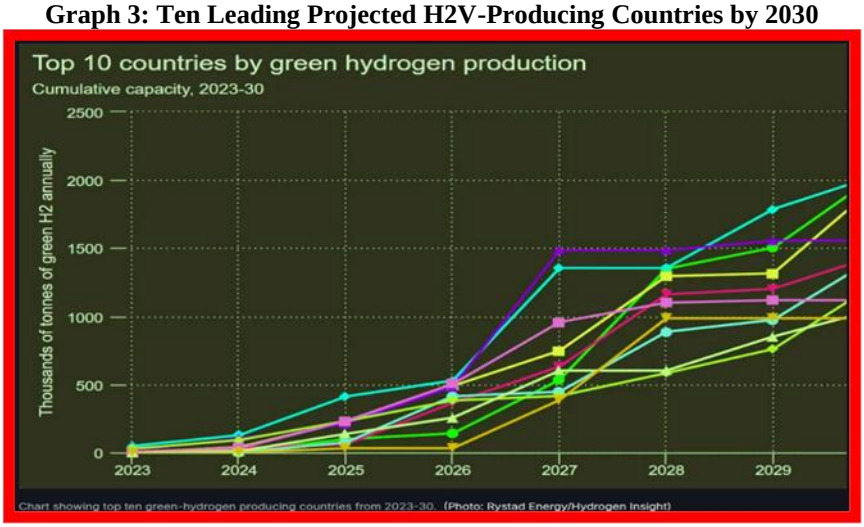
b. Rare

The IEA report "Renewables 2024: Analysis and Forecast to 2030" states that, despite increased political support, hydrogen produced from renewable energy is expected to account for only 4% of total H_2 production by 2030, mainly due to low demand. "Overall, it is projected to drive only 43 GW of new renewable capacity by 2030, representing less than 1% of the total global renewable capacity expansion" (IEA, 2024, p. 08).

The same report indicates that H_2 projects remain limited in driving additional renewable capacity growth until 2030. Between 2024 and 2030, renewable hydrogen production is expected to drive demand for an additional 45 GW of renewable capacity—less than 1% of the total global renewable capacity expansion. "The demand for new renewable capacity depends on market conditions and the regulatory environment" (IEA, 2024, p. 121).

Based on the aforementioned information, it can be inferred that H_2V may still be considered a rare product. On the other hand, Hydrogen Insight has identified ten countries projected to hold global relevance in H_2V production by 2030: Germany, Australia, Brazil, Canada, Chile, Egypt, Spain, the United States, India, and Morocco (Rystad Energy/Hydrogen Insight, 2023 apud FIEC, 2024). Given these projections of the ten most likely leading global producers, it can also be inferred that H2V may no longer be considered rare from a long-term global production perspective (Graph 3).

Graph 3: Ten Leading Projected H2V-Producing Countries by 2030



Source: Rystad Energy/Hydrogen Insight (2023).

c. Imperfectly Imitable

H_2V is obtained from renewable energy sources without carbon emissions through electrolysis, an electrochemical process that splits water into H_2 and O_2 (Oliveira, 2022). Thus, this energy commodity is perfectly imitable, provided it is produced through an adequate production chain that relies on renewable energy sources to break the water molecule.

d. Non-Substitutable

In this case, the industry offers alternative energy sources beyond H2V, including fossil fuels (oil, gas, and coal); renewables (hydroelectric, wind, solar photovoltaic, and geothermal); nuclear energy; and biofuels (biomass and bioenergy). Under these circumstances, H2V is not irreplaceable. Based on the analyses and evaluations conducted, studies indicate that H2V produced at the CIPP (Pecém Industrial and Port Complex) would have a perspective ranging from "competitive parity" (normal performance) to "temporary competitive advantage" (above-normal performance), as shown in Table 6. This allows for the inference that Ceará holds a competitive advantage in H2V production.

Table 6: Ceará's Competitive Advantage Perspective for H2V

Valuable?	Rare?	Difficult to Imitate?	Non-Substitutable?	Competitive Implications	Performance
Yes	No	No	No	*Competitive parity*	Normal
Yes	Yes	No	No	*Temporary competitive advantage*	Above Normal

Source: Adapted from Barney (1991 apud Guedes Laimer, & Rossato Laimer, 2009).

Regarding global competitors, it is evident that several countries possess high-quality resources for H_2V production, widely distributed across the globe. Additionally, many energy-exporting countries also have renewable resources that could be utilized for H_2V production (Oliveira, 2022). For this reason, the State of Ceará must continue its initiatives, implementing and fostering new ones to maintain global competitiveness against its rivals.

IV. Conclusion

Global warming, driven by greenhouse gas emissions, has led to a series of climate changes, causing environmental damage in several countries with significant socio-economic impacts. The increasing awareness of the international community regarding a more sustainable economy has gradually promoted the adoption of renewable energies, to the detriment of fossil fuels in the long term.

In this context, H_2V emerges as an alternative for energy transition and the decarbonization of the global economy. Ceará, in turn, stands out as a potential supplier of this renewable fuel due to a combination of favorable circumstances present in the state.

Thus, this study aimed to analyze the contributions of the Resource-Based View (RBV) in the current scenario of H_2V in Ceará. As a result of this analysis, it sought to provide senior managers with a situational framework that offers greater clarity on the business model, contributing to the development and consolidation of

competitive advantages for the state in comparison to its global competitors in producing and exporting this energy vector to the European market.

The research achieved its objectives, as it enabled an understanding of the applicability of RBV concepts within the complex and dynamic energy landscape involving governmental agencies, multinational corporations, and Brazilian industries that participate in the entire H_2V production cycle in the CIPP. Furthermore, the study demonstrated that RBV could contribute to the strategic management of stakeholders in Ceará's H2V market. Consequently, it would strengthen the state's existing competitive advantages over other global competitors.

The qualitative approach, based on literature and document review, was essential for understanding the variables that shape the energy market and the challenges of identifying strengths and opportunities for improvement within Ceará's internal environment. This effort aims to consolidate competitive advantages and foster new ones, ultimately strengthening the H_2V value chain at CIPP.

The theoretical findings reinforce the importance of employing strategic management tools and methodologies to identify capabilities and resources that enhance competitive advantages in favor of H_2V production and export to Europe. For future research, it is recommended to identify additional resources and capabilities in Ceará that could further enhance the state's competitive advantages, solidifying its position as a global player in the energy transition.

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