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# The Decision-Making Process for Developing Sustainable Innovation via Dynamic Capabilities in Cleantechs

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## Abstract

This article aims to present a model of how the decision-making process can drive the development of dynamic capabilities for generating sustainable innovation in cleantech companies. Cleantechs are highly technological organizations, one of whose main characteristics is little or no use of non-renewable resources to produce any type of product, service, or process. The use of these technologies and identification of opportunities in the market makes sustainable innovation the core competence of this type of company. A multiple case study was conducted with cleantechs using a qualitative approach, supported by the content analysis technique. The primary data collection was carried out via semi-structured interviews, between October of 2020 and December of 2021, using an interview script as a collection instrument. The results provide a model that illustrates how the decision-making process can drive the development of dynamic capabilities for generating sustainable innovations, by means of categories that reflect technological sustainability, spillover effects, and a drive toward digitalization in clean technologies. The scientific contribution of the study is the presentation of how organizations can restructure their business models and develop sustainable and technological innovations, digitally leapfrogging to address bottlenecks related to energy rationing, social inclusion through monitoring technologies, access to low-cost clean and renewable energy, and other solutions.

**Keyword:** effectuation and causation; dynamic capabilities; sustainable innovation; cleantech.

## Introduction

Sustainable innovation can be defined as the development of new products, processes, services, and technologies that can help in human wellbeing and in that of institutions. In the search for sustainable development, innovation and sustainability are recurrent themes in companies, governments, and institutions (Cillo, Petruzzelli, Ardito, & Del Giudice, 2019). Organizations and entrepreneurs have been driven to adopt technologies that have less environmental and social impact in different sectors of the economy (e.g. energy, sanitation, and transport) (George, Merrill, & Schillebeeckx, 2020).

In order for these technologies to be operationalized by organizations, the entrepreneur's decision-making process should be aligned with the environmental and inclusive premises of sustainability to seek innovation and socioeconomic advancement (Klewitz & Hansen, 2014). From the decision-making perspective, the entrepreneur can be mostly guided by two types of reasoning, namely effectuation and causation (Sarasvathy, 2001). When resorting to the logic of effectuation, decision making tends to be spontaneous, so that the entrepreneur seeks mechanisms they can control. On the other hand, with the causation logic, the entrepreneur starts with an objective, they chose the best way of achieving their goals, and they maintain a focus on what was already forecasted (Garrido et al., 2020; Sarasvathy, 2001). Created through the entrepreneurial motivation, different clean technology companies, known in the market as cleantechs, seek to combine their capabilities and resources in the technological and digital context to achieve sustainable business innovation (Aagaard, Saari, & Mäkinen, 2021; Bergman, Hajikhani, & Blomqvist, 2019; Gobble, 2012; Inigo, Albareda, & Ritala, 2017).

The authors Cumming, Henriques, and Sadorsky (2016), Bergman et al. (2019), and Giudici, Guerini, and Rossi-Lamastra (2019), whose studies focus on cleantechs, state that these companies are vectors of sustainable innovation, as they contain at their heart the mission to provide market solutions in harmony with the environment and society. Thus, they combine their market interests with technology and digitalization and they corroborate positively in the allocation of environmental resources (Cillo et al*.,* 2019; George et al., 2020). Also, some studies present the relationship between business models of a sustainable nature, which explore dynamic capabilities in search of a competitive advantage through innovations focused on solutions geared toward reducing carbon emissions, the adoption of clean and renewable energies, water use optimization, and monitoring of energy consumption to stimulate the efficiency of interlinked energy systems (Brink, 2019; Hansen, Grosse-Dunker, & Reichwald, 2009; Inigo et al., 2017).

In parallel, the paths of the sustainable innovation studies lay the scientific course between the entrepreneur's decision-making process and the orchestration of dynamic capabilities in the trajectory of combatting climate change through organizations focused on clean technologies (Bergman et al., 2019; George et al., 2020; Strauss, Lepoutre, & Wood, 2017). This scientific path opens up the way to investigate how sustainable innovations are presented in the context of cleantech companies (Aagaard et al., 2021) in particular, under the lens of the guiding logics of the effectuation and causation decision-making process (Dias, Iizuka, & Boas, 2019), as they reverberate in solutions that can provide innovations in processes, organizations, and products (Klewitz & Hansen, 2014), accelerating the debate and the knowledge needed for the multifaceted discussions of sustainable development (Sachs, Kroll, Lafortune, Fuller, & Woelm, 2021).

The decision-making process is the driving force for the creation of value based on different types of innovation in cleantechs (Aagaard et al., 2021; Ghorbel, Hachicha, Boujelbene, & Aljuaid, 2021). According to the directions of the literature, its direct connection with the elements of dynamic capabilities (Inigo et al., 2017) and sustainable innovation (Cillo et al., 2019) remains open, so that it is possible to build a scientific logic among the business solutions of clean technologies that enables us to delve deeper into their different effects for organizations, the economy, and society.

In this sense, the scientific gap that this paper seeks to address lies in the works of Ghorbel et al. (2021) and Aagaard et al. (2021), explaining that different decision-making models should be explored under the lens of the decision-making process, particularly effectuation theory. In addition, Klewitz and Hansen (2014) and Cillo et al. (2019) emphasize that sustainable innovation should be observed through the theoretical lenses of dynamic capabilities and resources, exploring contexts of different business organizations and innovations in processes, products, and routines.

Based on the aforementioned context presented during the introduction, the research question that guides this article is the following: **"How can the decision-making process drive the development of dynamic capabilities for generating sustainable innovation in the context of cleantech companies?"** To address the research question of the article, the study seeks to present a model illustrating how the decision-making process can develop dynamic capabilities for generating sustainable innovations.

The scientific contribution of the article lies in presenting how organizations can restructure their business models, using the decision-making process as a vector for developing sustainable and technological innovations, digitally leapfrogging to address bottlenecks related to energy rationing, social inclusion through monitoring technologies, access to low-cost clean and renewable energy, and other solutions presented throughout the results of the research.

The practical contribution, in turn, lies in the organizational context of cleantechs, highlighting the organizational-innovative potential of that company model, so as to consolidate a road map of decentralized and technological innovations for entrepreneurs, governments, and universities seeking solutions for the sustainable development challenges and goals outlined by the United Nations Organization (UN). For that, the methodological path involved a qualitative study using a multiple case approach. Semi-structured interviews were applied during the period from 2020 (October) to 2021 (December) in Brazilian organizations characterized as cleantechs.

Including the introduction, the structure of the article is divided into six stages. The second stage is the theoretical framework, addressing the main theoretical foundations and references of the article: the decision-making process, effectuation theory, dynamic capabilities, and sustainable innovation, as well as the creation of propositions and research. The third stage describes the methodological course of the research. The fourth involves the data analysis conducted based on content analysis. In the fifth stage, the results and discussions of the analyzed data are presented. And, finally, the concluding remarks contemplate the directions, limitations, and fulfillment of the scope of the research.

## Theoretical framework

The foundations of the theoretical framework used for the present study include: (a) the decision-making process: effectuation theory; (b) dynamic capabilities; and (c) sustainable innovation. The driving foundations were chosen due to the characteristics of the research phenomenon, culminating in the elaboration of the proposition premises, examined in more depth in the model proposition section.

The (a) decision-making process foundation is articulated in accordance with the entrepreneurial initiative from the perspective of effectuation theory by Sarasvathy (2001) and Sarasvathy, Dew, Read, and Wiltbank (2008), leading to the development of dynamic capabilities (Teece et al., 1997). In addition, (b) dynamic capabilities are explored in light of the theoretical lenses proposed by Teece and Pisano (2003) and Teece (2017), operating the sensing, seizing, and reconfiguring, for the development of (c) sustainable innovations. Sustainable innovation, in turn, is observed through the organizational innovation processes, process innovation, and product innovation, from the socioenvironmental and economic perspective of the businesses (Cillo et al., 2019; Klewitz & Hansen, 2014).

### *Decision-making process: effectuation theory*

The decision-making field of science began to be highlighted with the emergence of the book *Administrative Behavior*, from Herbert Simon, in 1947. Simon addressed the decision-making process from a rationality perspective. For Simon, decisions are conscious choices between two or more alternatives with a well-defined objective. Decision-making processes can be planned or unplanned. Planned ones are routine and repetitive, and as such they require less effort from the manager. On the other hand, unplanned ones are unique decisions that require planning and investigation (Bertoncini et al., 2013).

Another dimension of the decision-making field are the decision-making processes based on the perspective of entrepreneurial studies that cover the science of effectuation theory (Dias et al., 2019), whose conceptual characteristics are examined in more depth in this section. From this perspective, the entrepreneur is an agent that takes organizational decisions to leverage company performance in the market, by adapting and transforming opportunities into innovations and contingences into opportunities (Ghorbel et al., 2021; Roach, Ryman, & Makani, 2016).

Entrepreneurship and innovation are interdependent concepts, since, in order to manage the innovation process, the entrepreneur adopts the effectuation approach (Barzotto & Nassif, 2019; Ghorbel et al., 2021; Roach et al., 2016). Entrepreneurship is associated with the perception and seizing of opportunities and the creation of new businesses or design of businesses in new/innovative ways (Baron & Shane, 2015; Barzotto & Nassif, 2019; Shane & Venkataraman, 2000). The creation and design of businesses, in turn, are fundamental in the generation of wealth and innovations (Dew & Sarasvathy, 2007). So, it is necessary to understand how the creation and decision-making processes of entrepreneurs occur (Ghorbel et al., 2021) and how the effort of entrepreneurs is geared toward adapting and transforming opportunities into successful innovations. Adaptation and transformation constitute the key idea of effectuation theory (Aagaard et al., 2021; Roach et al., 2016).

Effectuation theory unfolds into two complementary logics: effectuation and causation (Sarasvathy, 2001; Sarasvathy et al., 2008). At the moment of making a decision, the entrepreneur should dose the two possible logics for guidance. These logics can be more spontaneous, a plan, or predefined model (effectuation), assuming a set of means as given and focusing on the selection of possible effects that the entrepreneur can create with that set of means to determine what they can control (Sarasvathy, 2001). That process contrasts with the methodical and ordered logic (causation), in which a particular objective is given and the entrepreneur focuses on selecting the most appropriate means for creating and achieving that predefined goal, focusing on prediction instead of control (Garrido et al., 2020; Sarasvathy, 2001). Both decision-making logics can relate to a particular decision or a series of decisions, or even to a tendency to emphasize causation and/or effectuation within the organization (Harms, Alfert, Cheng, & Kraus, 2021).

The tendency toward to the causal logic is based on goals/objectives, on planning, and on the recognition of opportunities, being guided by analyses of the competition, pre-existing knowledge, and estimated returns. On the other hand, with the emphasis on a mostly effectual view, the entrepreneur uses four key concepts and three guiding principles as a basis for operationalizing that logic (Sarasvathy, 2001; Sarasvathy et al., 2008; Kalinic, Sarasvathy, & Forza, 2014). The conceptual basis is subdivided into (a) flexibility, which covers reasoning guided by continuous improvement, constant evolution; (b) experimentation, in which the logic is based on gradual learning and on tolerance of errors; (c) justifiable loss, which is based on the equilibrium point at which the possible loss (the risk) is acceptable; and (d) prior commitments, which covers informal alliances and networks, with this dimension referring to the selection and commitment of the different interested parties (stakeholders) (Barzotto & Nassif, 2019; Kalinic *et al*., 2014; Sarasvathy, 2001). The main guidelines are linked to the entrepreneur/individual: (a) who I am (personality), what I know (experience), and who I know (network of contacts) (Kalinic et al., 2014; Roach et al., 2016; Sarasvathy et al., 2008).

According to Roach et al. (2016), the principles of effectuation were based on an evolution of the practice of business innovation. Thus, they include many types and conceptions of business innovation and are intimately linked to innovation. The different methods of innovation impacted by the decision-making processes can enable dynamicity and a consumer-based approach, which are essential for validating business models, the product cycle, opportunities, and the co-creation of new markets (Ghorbel et al., 2021; Roach et al., 2016).

Also, by balancing the effectual and/or causal logics, the actions of entrepreneurs unfold in/drive the dynamic capabilities included in the dimensions of sensing, seizing, and reconfiguring, to be examined in more depth further on. According to studies of Sarasvathy (2001) and Sarasvathy et al. (2008), using the decision-making logics as a basis, entrepreneurs employ existing resources to identify opportunities; they identify opportunities resulting from market failures by investigating factors that delay the achievement of their objectives; they take advantage of contingences; they establish strategic relationships with stakeholder; and they take investment decisions from the perspective of acceptable loss. So, the entrepreneur creates and re(configures) resources to identify and take advantage of opportunities (Roach et al., 2016; Sarasvathy, Kumar, York, & Bhagavatula, 2014; Silva, 2020).

In addition, Teece et al. (1997) highlight that strategic management is essential for achieving "adaptation, integration, and reconfiguration of internal and external organizational abilities,

resources, and competences" (p. 515). Thus, through the decision-making logics, entrepreneurs drive the sensing, seizing, and reconfiguration of opportunities, resources, and competences.

### *Dynamic capabilities*

Dynamic capabilities are abilities developed using the resources in the organizational environment and are essential for the company's performance (Teece et al., 1997). Built throughout the journey based on knowledge and experiences, the set of abilities that includes individuals, human resources, and the company's intellectual property can integrate, build, and reconfigure businesses (Strauss et al., 2017; Teece, 2017, 2018). To obtain sustainable competitive advantages, it is necessary to define the abilities for correctly allocating the resources and continuously promoting capabilities that generate sustainable innovation that are hard to imitate (Helfat & Peteraf, 2015; Teece & Leih, 2016; Cillo et al., 2019).

The study of dynamic capabilities is based on the study of the resource-based view (RBV) proposed by Teece et al. (1997) when highlighting the importance of developing dynamic capacity resources in business processes and routines, emphasizing that these capabilities are rare, inimitable, and hard to substitute. With the intention of implementing better practices in relation to the competition, Teece et al. (1997) and Teece (2017) divided dynamic capabilities into three dimensions, namely sensing, seizing, and reconfiguring. Teece's (2017) dimensions are consolidated and adapted in Table 1 from the perspective of the research of Garrido, Kretschmer, Vasconcellos, and Gonçalo (2020).

Table 1

**The dimensions of dynamic capabilities**

| Dimension | Characteristic of the dimension of dynamic capabilities | References |
|---|---|---|
| *Sensing*: Perceiving threats to overcome with opportunities and technologies in the market. | Investment in R&D; identifying customer needs; collecting information from different sources; monitoring the business' structural evolution and technology; acquiring, accumulating, and sharing tacit knowledge; developing routines for formulating new ideas. | Brink, 2019; Garrido et al., 2020; Inigo et al., 2017; Teece, 2017, 2018; Teece et al., 1997. |
| *Seizing*: Transforming opportunities into new products, services, and processes. | Developing new products and processes; investing in technology; improving and developing new business models; combining knowledge; developing routines for internalizing knowledge for strategic decisions. | Brink, 2019; Garrido et al., 2020; Inigo et al., 2017; Teece, 2017, 2018; Teece et al., 1997. |
| *Reconfiguring*: Reconfiguring assets and the organizational structure to ensure the company's evolution. | Defining partnerships in the value chain; decentralizing activities; orchestrating assets, aligning them, and redistributing them; capacity to integrate, share, and monitor knowledge; exploring the creation of new knowledge; widening collaboration networks to generate resource combinations; abandoning combinations and processes that do not generate competitive advantages. | Brink, 2019; Garrido et al., 2020; Inigo et al., 2017; Teece, 2017, 2018; Teece et al., 1997. |

Source: Adapted from Garrido et al. (2020).

The challenge proposed in the companies is that of seeking profits in a sustainable way, based on, for example, the identification of developed dynamic capabilities, the development of supply chain processes, and the involvement of the whole set of processes, with these being key elements for creating low-cost value proposals that enable sustainable innovation (Inigo et al., 2017).

Dynamic capabilities represent an important mechanism for addressing the sustainable innovation process (Brink, 2019; Inigo et al., 2017). Companies need to prepare their physical resources with abilities to identify new technological trends for innovation from the perspective of mitigating threats and generating new opportunities (Teece, 2010).

In the sense of corresponding to the environment of new changes, Teece (2017) employs technological capabilities with the aim of promoting digitalization and innovation and accompanying the changes articulated by competitors. The authors Achtenhagen, Melin, and Naldi (2013) highlight the importance of developing higher-order dynamic capabilities. Thus, the technological capabilities developed using the resources are sources for generating new ideas to promote the company's sustainable innovation (Mezger, 2014).

The changes in the global panorama of companies imply new initiatives geared toward sustainable innovation (Inigo et al., 2017; Klewitz & Hansen, 2014). This key change involves decision-making processes for innovation, and individuals and companies develop abilities for supporting new strategies (Brink, 2019; Klewitz & Hansen, 2014). Therefore, the decision-making process for achieving sustainable innovation, in this study, has deep links with the foundations of dynamic capabilities (Cillo et al., 2019).

### *Sustainable innovation*

The innovation studies began with the works of Joseph Schumpeter, which had an economic/industrial bias. For the author, innovation translates into the introduction of a new product or new combinations of something that already exists (Schumepter, 1934). Innovation and evolution occur through a cycle in which one entrepreneur attracts another, thus multiplying the effects of the network.

However, for this study, we will adopt the line of Klewitz and Hansen (2014) and Cillo et al. (2019) to observe sustainable innovation in the context of cleantech companies, since the concept if positioned as a premise resulting from the combination of the foundations of the decision-making process and of dynamic capabilities. Sustainable innovation can occur from the perspective of three strategic elements of innovation, which should be aligned with social, environmental, and economic questions: (a) process innovation; (b) organizational innovation; and (c) product innovation (Boons & Lüdeke-Freund, 2013; Klewitz & Hansen, 2014). Next, we present the definition of three dimensions of innovation, from the perspective of sustainable innovation, which serve as guides for the application of the collection instruments of the present study:

- **Process innovation**: This is associated with the methods and techniques for producing goods and services that increase the sustainable efficiency of market solutions (Cillo et al., 2019; Gobble, 2012). Process innovation is associated with the use of clean technologies for providing market solutions that increase environmental and ecological

efficiency, visualizing an economically viable scenario for businesses. Klewitz and Hansen (2014) reinforce the idea that innovative processes are related to questions of logistics, carbon footprint, clean energy production, and ecoefficiency.

- **Organizational innovation**: This is related to the restructuring of organizational routines, exploring new forms of management and the capacity to reconfigure the characteristics of the organization's assets (Cillo et al., 2019). The technological systems used enable innovation in the organization, adopting new governance structures that pursue environmental, social, and inclusive goals, reverberating in the supply chains and work flows in the companies (Boons & Lüdeke-Freund, 2013; Klewitz & Hansen, 2014). The automation and optimization of routines using technology and digitalization enable the organizational innovation to address socioenvironmental factors in the business models (George et al., 2020).
- **Product innovation:** This is based on the refinement, enhancement, or development of new products and services, focused in design, materials, and quality standards that provide novelties in the market using a sustainable approach (Cillo et al., 2019; Hall, Daneke, & Lenox, 2010). These innovations can help with efficiency and reducing energy consumption and water waste, developing non-renewable sources toward renewable sources, and technological solutions that can be added to existing products and services to stimulate sustainability in the businesses in an innovative way, covering the social, economic, and environmental dimensions of the businesses (George et al., 2020; Klewitz & Hansen, 2014).

However, to understand these dimensions from the perspective of sustainable innovation, it is necessary to step back and analyze the concept of sustainable innovation. This concept is rooted in the scientific bases of technological innovation and resource allocation for the development of new products and services, seeking the socioenvironmental responsibility of businesses (Friedman, 2007; Gobble, 2012; Hansen et al., 2009). Sustainable innovation involves the development of new products, processes, services, and technologies that contribute to the wellbeing of humanity, focusing on environmental and social factors and their capacity to mitigate impacts, based on the use of resources derived and extracted from the environment (Cillo et al., 2019).

From the perspective of the organizations, sustainable innovation is the innovation process that consists of renovating and enhancing products, technologies, and organizational processes and reflects economically, environmentally, and socially in the performance of organizations, generating solutions that reduce the impact on the businesses (Boons & Lüdeke-Freund, 2013; George et al., 2020). In addition, sustainable innovation is articulated from the socioenvironmental and financial perspectives, integrating the processes and systems of the companies that involve the research and development (R&D) work in the businesses (Cillo et al., 2019; Klewitz & Hansen, 2014).

In an in-depth review of the literature, the authors Klewitz and Hansen (2014) indicate that sustainable innovation can manifest in companies in certain strategic behaviors that are linked to types of innovation, such as the improvement of organizational resources, product innovations, innovation in business models, and even radical changes of products. These types of innovation are subject to the interaction of different stakeholders (e.g. market, government, regulatory agencies) that stimulate the company to adopt its strategic position in search of sustainable innovation.

In addition, Cillo et al. (2019) affirm that sustainable innovation can be stressed from the perspective of different theoretical lenses when observing the business context. Among those theoretical lenses are fundamentals linked to dynamic capabilities, company resources, and knowledge management. For the authors, these are theoretical lenses of the scientific knowledge that should be further examined in order to understand how sustainable innovation is presented in different organizational contexts, addressing research gaps presented throughout the scientific literature (Inigo et al., 2017).

### *Theoretical model of propositions*

From the perspective of the effectuation theoretical lens, at the moment of decision making, entrepreneurs use knowledge, alliances, and pre-existing networks as a basis (Silva, 2020). Over time the cycle feeds back, improving with more discoveries, creation, and development of capabilities and opportunities (Chandra, Styles, & Wilkinson, 2015). Thus, entrepreneurs start by analyzing the organization's resources and capabilities in order to, through configuring and taking advantage of those capabilities, create opportunities in unknown markets (Kalinic et al., 2014). This logic is particularly beneficial in dynamic contexts, in which the main objective is to solve problems through the creation of opportunities (Kalinic et al., 2014).

In resonance, by investigating the identification of opportunities in the context of joint ventures, Mainela and Puhakka (2009) use the concepts of effectuation as a basis. In their study, they find that opportunities are identified and created based on the state of alert, on the creativity, and on the flexibility of the entrepreneur, with a strong influence of partnerships on the result of the creation. Also, dynamic capabilities make it possible to effectively execute the strategic intention (Shuen, Feiler, & Teece, 2014). To identify, develop, and explore opportunities, it is essential for the entrepreneur to be agile in their decisions, precise in their timing, and assertive in the generation of value, with the entrepreneur's own dynamic capabilities thus being important (Peiris, Akoorie, & Sinha*,* 2015).

The entrepreneur has the responsibility of leveraging the application of resources and capabilities. Similarly, they need to be capable of constantly reconfiguring those resources and capabilities to obtain different outputs and, thus, create opportunities, innovation, and competitive advantage. Therefore, the entrepreneur, just like their decision-making logic, is central to the dynamic capabilities. The entrepreneur is responsible for leveraging the application of the resources, so that the same resources can generate different results according to their actuation (Roach et al*.,* 2016; Sarasvathy et al., 2014; Silva, 2020). Given that effectuation unfolds into two decision-making logics, in the present study, the role of those logics will be examined based on two propositions, in order to explore both through the creation and use of opportunities and capabilities. The influence of the two decision-making logics can be observed in the three dimensions of the dynamic capabilities established by Teece (2017): sensing, seizing, and reconfiguring.

**Proposition 1**: The decision-making process based on the effectual logic drives the use of dynamic capabilities.

**Proposition 2**: The decision-making process guided by the causal logic enables the identification and generation of dynamic capabilities.

Therefore, what is proposed is that based on the effectual and causal logics there is the use and generation of dynamic capabilities. It is also proposed that this process culminates in the generation of sustainable innovation (Figure 1), according to proposition 3, presented below. These propositions are based on the aforementioned literature and will be investigated through the case study in cleantech companies.

**Proposition 3**: The dynamic capabilities articulated through the decision-making process generate sustainable innovation.

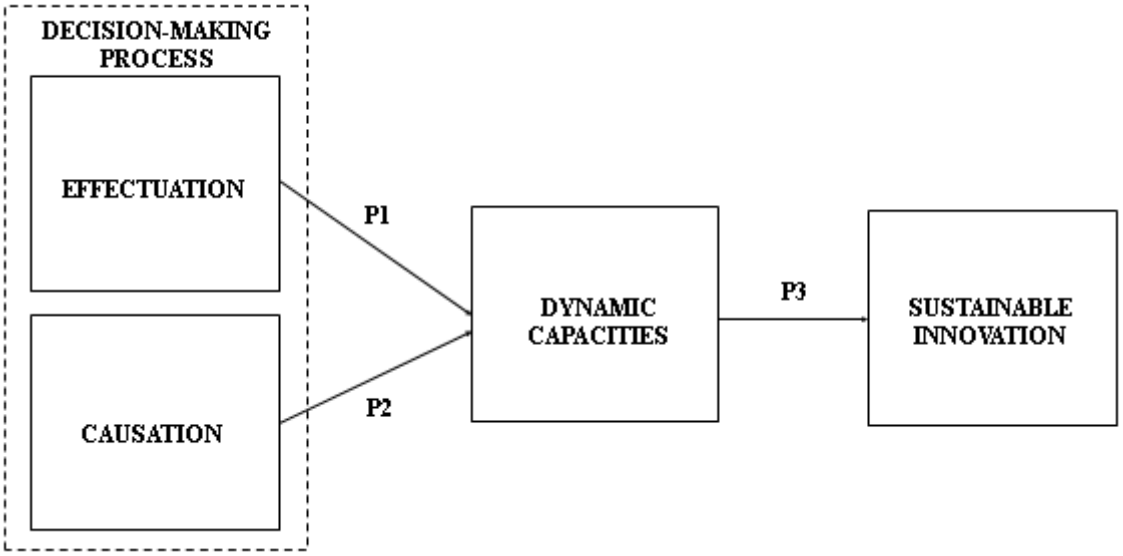


**Figure 1.** Theoretical model of propositions

Source: Elaborated by the authors.

## Methodology

The methodological approach of the present article is based on descriptive qualitative methods, to be explained below. The research involved the multiple case study of entrepreneurs from cleantech organizations that fit the established criteria. In addition, content analysis was applied with the support of the MaxQDA software, which enabled the transcribed interviews to be imported to speed up the analysis and the process of categorizing the passages from the survey. Software was used to support the content analysis, as it enables the robust absorption of data, facilitating improved qualitative inferences.

### *Research approach and method*

The research used a qualitative method of a descriptive nature to understand, observe, and analyze the phenomenon studied. This method enables the researchers to draw closer to the study object through the theoretical lenses, understanding the layers present during the event studied. In light of that, the method enables the researchers to capture all the elements involved during the event and to collect the maximum amount of data possible, with them being obliged to consider each and every data item in the field (Sandelowski, 2000).

The research was elaborated through the observation and analysis of multiple cases. The multiple cases present similarities of the phenomenon studied between the objects of study, reducing the possibility of analyzing a single perspective of the object (Yin, 1994). The multiple pieces of evidence enable the exclusion of unique particularities and, when convergent with each other, they raise the reliability and robustness of the method, supporting the inferences based on the theoretical framework (Zainal, 2007).

In turn, these choices in relation to the method used and to the approach sustain the interest in being able to respond to the research problem through the "how." This, in light of other methods, would make it hard to access the identification and analysis needed to overcome the peculiarities of the question at hand (Sandelowski, 2000).

### *Methodological path for the case study*

The methodological path taken in this study is based on and adapted from the one proposed by Hafiz (2008), dividing the processes into eight main stages. This flow proposed for the case study tries to treat complex situations simply. In this sense, the research seeks to convert and clarify a phenomenon under study, following the flow presented in Figure 2.

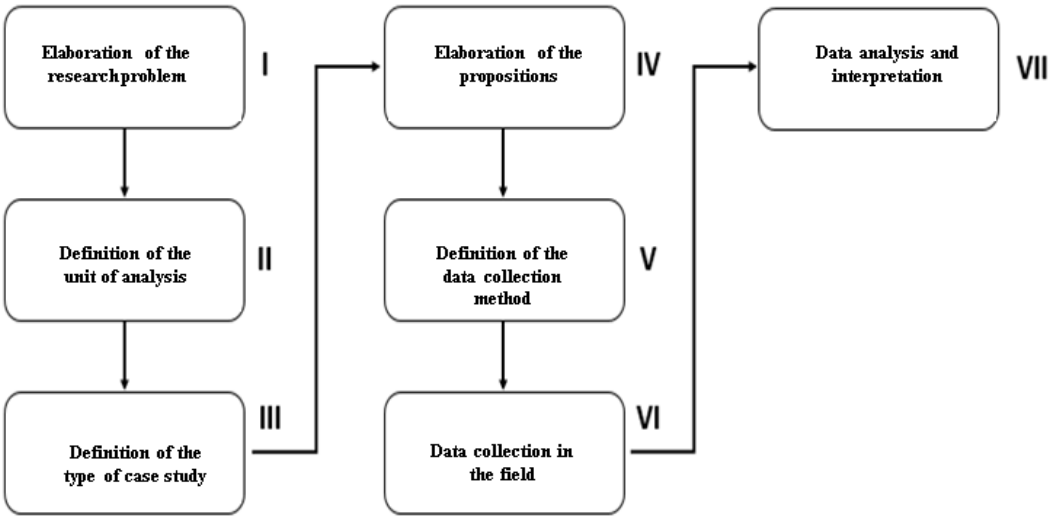


**Figure 2.** Stages of the case study

Source: Elaborated by the authors.

### *Collection instrument and collection period*

The primary data collection was carried out through semi-structured interviews, between 2020 (October) and 2021 (December), using an interview script as a collection instrument (Appendix 1). The use of this collection method enables the interviewer to guide the interview through the lens of the theoretical framework and, also, for the interviewee to have the freedom to reveal facts that are beyond the perspective analyzed and that may be relevant to the study (Yin, 2015).

The interview script was created based on the propositions elaborated in light of the theoretical framework, in order to obtain answers that could contribute to understanding the phenomenon. The use of that collection instrument enables the interviewer to prepare previously and be able to verify whether the questions are consistent with the study objective, evaluating possible improvements before implementing the research. In addition, it enables the interviewer to choose to maintain or not the interviews throughout the course of the theoretical framework (Kallio, Pietilä, Johnson, & Kangasniemi, 2016).

### *Research context: cleantech companies*

The study object used to analyze the research problem consists of Brazilian cleantech companies. Cleantechs are highly technological organizations whose main characteristic is little or no use of non-renewable resources to produce any type of product, service, or process. The use of these technologies and the identification of opportunities in the market make sustainable innovation the core competence of this type of company (Bergman et al., 2019; Cumming et al., 2016).

Given the context, cleantechs have specific characteristics, through being concerned about the environment and making use of ecologically correct resources combined with the intensive use of technology. They are companies focused on clean technologies that are strong allies in providing energy savings and combatting pollution, contamination, and environmental impact (Pernick & Wilder, 2007).

Cleantechs have four main areas of activity: transport, energy, water, and minerals (De Noronha et al., 2022). These market segments of cleantech companies incorporate processes, technology, goods, and services that have been developed to mitigate the negative environmental effects and enable the sustainable use of natural resources. Cleantechs came to exist primarily due to market demand, based on certain needs, for example water treatment, the reduction of air pollutant emissions and heavy industry gases, and energy reduction, among others (De Noronha et al., 2022). Therefore, cleantechs can be configured in industries, businesses, and various value chains.

The core commitment of cleantechs is to include technology products and services supported by knowledge to promote better behavior with lower costs. The proposal of these companies is to reduce negative ecological impacts and use natural resources responsibly (George et al., 2020). With that objective, their organizational routines are consolidated through automated processes housed in technology and innovation, enabling the remodeling of those routines to promote the creation of new sustainable products for the company (Cillo et al., 2019).

The characteristics of this type of company put it in a highly dynamic, innovative, and technological business environment (Giudici, Guerini, & Rossi-Lamastra, 2019). The constant changes in the environment and the environmental challenges form a context of future uncertainty and of opportunities or needs for the emergence of entrepreneurship, consistent with the objectives of this study (Wüstenhagen, Sharma, Starik, & Wuebker, 2008).

### *Criteria for selecting the sample and its characteristics*

The criteria for selecting the companies were: (a) being a cleantech and having technological solutions of a sustainable nature; (b) being located in Brazil; and (c) having access to influential entrepreneurs in the organization's decision-making process. These criteria were chosen due to the need to understand the decisions of the entrepreneurs of the companies involved in a highly dynamic, technological, and innovative business environment, consistent with the direction of the theoretical foundations chosen.

The interviews were conducted with 17 entrepreneurs of companies denominated as cleantechs with headquarters in Brazil. The interviews were conducted between October of 2020 and December of 2021 in on-site and virtual (via online platforms) modalities, lasting 38.35 minutes on average, and being recorded in full for subsequent transcription of their contents. Throughout the collection, it was observed that there was major convergence between the results found and there were no appearances of new data that were substantially relevant for the research, thus reaching the saturation point. Therefore, no more reports were collected, and the characteristics of the sample are specified in Table 2. Hence, the saturation point occurred at 17 interviews (Guest, Bunce, & Johnson, 2006).

Table 2

**Characteristics of the sample**

| Entrepreneur interviewed | Company | Scope of the cleantech's activities | Interview time | Interview date |
|---|---|---|---|---|
| ***Interviewee 1*** | *A* | *Financial credits for implementing solar energy* | *42':12"* | *October, 2020* |
| ***Interviewee 2*** | *B* | *Commercialization of renewable energy certificates* | *37':11"* | *October, 2020* |
| ***Interviewee 3*** | *C* | *Monitoring of energy consumption, optimization, and energy efficiency* | *26':37"* | *December, 2020* |
| ***Interviewee 4*** | | | *44':02"* | *February, 2021* |
| ***Interviewee 5*** | *D* | *Commercialization of solar energy* | *35':01"* | *February , 2021* |
| ***Interviewee 6*** | *E* | *Sanitation and water treatment* | *45':52"* | *April, 2021* |
| ***Interviewee 7*** | | | *40':44"* | *April, 2021* |
| ***Interviewee 8*** | *F* | *Commercialization of solar energy* | *39':22"* | *March, 2021* |
| ***Interviewee 9*** | | | *29':12"* | *March, 2021* |
| ***Interviewee 10*** | *G* | *Energy and mobility* | *31':23"* | *June, 2021* |
| ***Interviewee 11*** | | | *45':56"* | *June, 2021* |
| ***Interviewee 12*** | *H* | *Carbon capture* | *44':10"* | *August, 2021* |
| ***Interviewee 13*** | | | *36':12"* | *August , 2021* |
| ***Interviewee 14*** | | | *33':17"* | *August , 2021* |
| ***Interviewee 15*** | *I* | *Systems for monitoring wind farms* | *28':09"* | *November, 2021* |
| ***Interviewee 16*** | *J* | *Monitoring of energy consumption, optimization, and energy efficiency* | *49':12"* | *November, 2021* |
| ***Interviewee 17*** | *K* | *Digital consulting for reducing energy consumption and an energy services platform* | *50':22"* | *December, 2021* |

Source: Elaborated by the authors

## Levels of analysis of the sample

Due to the research context and the choice of the theoretical lenses used to observe the phenomenon, four analysis levels were initially separated to fit the main results obtained through the data analysis and report assessment. These analysis levels are: (1) **entrepreneur level**; (2) **organizational level**; (3) **level of sustainable innovations of the cleantechs**; and (4) **effects of the clean technology innovations**. The analysis levels of the sample are detailed in the items below:

1. **Entrepreneur level**: This is associated with the choice of the entrepreneurs of the cleantechs themselves and their initiatives, which are linked to the lines of the effectuation and causation decision-making process. This level covers the initiatives employed that involve contexts of the organizations. It also considered an assessment of solutions that include the customers of the cleantechs and how they may be positively or negatively impacted by the entrepreneurial initiatives and by the decision-making process.

2. **Organizational level**: This covers the internal practices that translate the lens of dynamic capabilities and are linked to initiatives of the decision-making processes, affecting how the cleantech organizations operate their solutions in relation to the sensing, seizing, and reconfiguring categories. This analysis level was observed from the internal perspective of the company with entrepreneurial support for the generation of sustainable innovation, creating a theoretical axis for the structuring of research propositions.
3. **Sustainable innovations in the cleantechs**: This represents the determination of the categories derived from the sustainable innovation reference, based on the following categories: (a) process innovation; (b) organizational innovation; and (c) product innovation. This level is observed as a result of the combination of levels A and B, visualizing the innovations provided by the cleantechs chosen for the sample and their specific technological and digital characteristics for fostering innovations with an environmental, social, and economic impact.
4. **Effects of the clean technology innovations**: This level is linked to the effects caused by the decision-making process initiatives and to the relationship with the organizational and sustainable innovation context. The main findings of the research are evaluated according to the application of innovations led by the decision-making process of the entrepreneurs that reverberate in the organizations.

### *Data analysis technique: research categories and software used*

The analysis technique used was content analysis with data triangulation, following an analysis path based on a number of stages (Elo & Kyngäs, 2008). The triangulation technique was applied in this research to contribute to the quality of the findings and to compose the analysis process. The data collected were extracted from the main sources, namely interviews, observations and field notes, and documents derived from websites and from the sector of the organizations chosen for research (Decrop, 1999).

Triangulating the data contributes to the qualitative research method and reinforces the validation of the materials collected (Shenton, 2004). Therefore, the processes used in this research were: (a) choice of the approach; (b) reading of the data collected; (c) classification of the deductive data; (d) systematization of the data via software; and (e) categorization of the data, as Figure 3 shows.

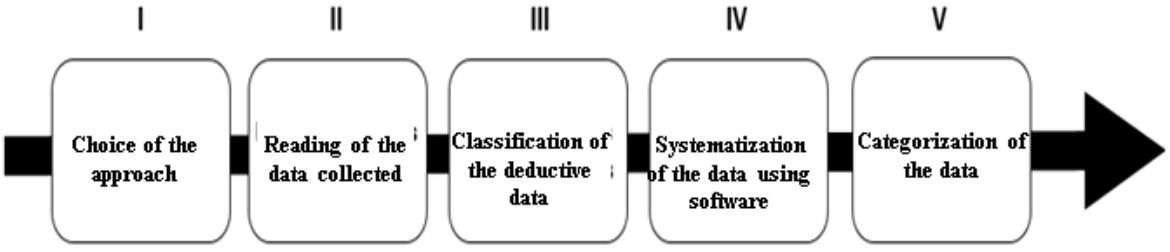


**Figure 3.** Course of the data analysis

Source: Elaborated by the authors

The content analysis technique enables an evaluation and comparison of inferences regarding values, feelings, intentions, and ideologies of the agents that generated the collected data. These dimensions are fundamental for understanding relevant questions in the entrepreneur's decision-making process related to the cleantechs and their dynamic capabilities and innovations (Morris, 1994).

The global advancement of technology enabled the creation of the categories and classification of the data analyzed in light of the content analysis to be carried out using computerized systems. The use of the MaxQda software for systematizing the data sustains the reliability for classifying a large quantity of data, as is the case of this research (Morris, 1994). The MaxQda software enables the transcribed interviews to be imported and helps in the analysis and interpretation of the collected data, facilitating the codification and sharing of the analyses among researchers. Thus, the choice of the MaxQda software for this research was due to the need to codify the passages from the interviews and, additionally, due to the agility provided by the systematization of the content. MaxQda enables the researchers to highlight important parts for the analysis and employ categories that give greater robustness to the content analysis.

Initially, deductive categories were used, as proposed by Elo and Kyngas (2008). The deductive categories are those created based on the theoretical framework, according to the construction of the interview script previously built. However, during the period of analyzing the collected data, we verified the emergence of categories that were relevant to the study and that were not foreseen in the theoretical framework, making it necessary to create the inductive categories to fully understand the phenomenon (Elo & Kyngas, 2008). In this study, the inductive categories are called **emerging categories**, to facilitate the understanding of the data analysis in the next section.

## Analysis and discussion of the results

### *Content analysis*

The content analysis section of the present article is structured via an analysis of the reports transcribed during the work. To carry out the analysis, the deductive approach was used, in which we chose the main reports representative of the categories found in the theoretical framework and that symbolize the repetition number, illustrating the objective established by the work (Table 3). The repetition number represents the statistical incidence of repetition identified by the MaxQda software. This incidence indicates the relevance of the theoretical category operationalized during the study, directing the in-depth examination of the concept via the collection instrument (script). As indicated in the methodology section, the technique employed is content analysis, aiming to semantically analyze the proposed text, through the theoretical lenses chosen for the research.

To organize the analysis format, the present article divides the work into four blocks: (a) **decision-making process**; (b) **dynamic capabilities**; (c) **sustainable innovation**; and (d) **emerging categories**, corresponding to the adjacent subsections of the present article. The division by blocks establishes according to the evaluation each category that represents the subconcepts explored in the theoretical framework (Elo & Kyngas, 2008).

Block a, the decision-making process, delves deeper into the qualitative results from the perspective of the effectuation and causation categories. Block b, dynamic capabilities, presents the main reports regarding the sensing, seizing, and reconfiguring categories. Block c, sustainable innovation, translates the main reports corresponding to process innovation, organizational innovation, and product innovation from the sustainable perspective. In turn, block d, emerging categories, represents the findings of the research that emerged beyond the theoretical lenses chosen to analyze the object of the study.

Table 3

**Reports, categories, and incidences**

| Block | Analysis categories | Repetition | Representative transcription |
|---|---|---|---|
| Decision-making process | Effectuation | 15 | "The commercialization of renewable energy certificates is for any entrepreneur that seeks to make their products sustainable and structure their business model focusing on the environment. The entrepreneur can choose to buy wind, solar, or biomass energy certificates and certify the "renewableness" of their business' energy supply… This technology is also already made viable by blockchain." (Interviewee 2, 2020)<br><br>"The credit and access to produce their own solar energy give autonomy to the vendors to not depend on more expensive and non-renewable energy. The entrepreneurs come to have the choice of the type of energy, using a system of energy offsetting established by ANEEL (National Electrical Energy Agency) itself." (Interviewee 1, 2020) |
| | Causation | 19 | "The monitoring systems store the data in the cloud... We can plan the strategies for the different types of consumer and they choose the best options for reducing their consumption. The cloud and data storage technology means we can offer different energy solutions for the customer to be able to economize in their day-to-day bill. These solutions for businesses range from exchanging rubbers for fridges to buying solar energy quotas, reducing the entrepreneurs' costs and providing an outlook for fixed costs…" (Interviewee 3, 2020) |
| Dynamic capabilities | Sensing | 29 | "The existing devices give mobility for us to understand each customer's consumption behavior… We have an intelligence which by means of satellites we can identify the different climate changes and monitor prices and send notifications to the consumers in periods spent… The algorithms can also map specific data to differentiate the customers and with those insights we can improve our service plant and provide specific options for different consumers, giving autonomy to choose products over the internet of things (IoT) in smart metering." (Interviewee 5, 2021) |
| | Seizing | 22 | "... we have a technological and digital monitoring network for reducing waste and losses in water consumption and spillages… the artificial intelligence sensors detect the repairs needed and with maintenance support it is possible to resolve spillage problems in real time. This on a large scale can provide unmeasurable gains for residents of big cities like São Paulo. To get an idea, today Brazil loses 38% of the water it collects from rivers during its distribution. To understand the proportion of that volume, if we saved approximately 20% of what we lose, we'd have enough water to supply 35 million Brazilians without access to drinking water. Brazilians lose a lot of water and financially that represents a cost of 10 billion reais every year." (Interviewee 7, 2021) |

| | | | |
|---|---|---|---|
| | Reconfiguring | 31 | "The changes in the current rules for the commercialization and offsetting of energy applied by ANEEL have enabled the commercialization of solar energy quotas. Entrepreneur owners of bakeries, restaurants, and stores can buy energy without installing solar panels… It was a rapid adaptation for commerce and to the opportunities that opened up for the energy sector because we know that the National Interlinked System of energy is complex and involves a series of structural questions that depend on energy transmission and distribution to major centers." (Interviewee 9, 2021) |
| Sustainable innovation | Process innovation | 38 | "The renewableness of the grid is very important for urban mobility and will be fundamental for a sustainable future, considering that most of the fleet of cars in the world is gasoline and fossil fuel based… The launch of new cars, electric power points, and even the re-adaptation of the production chain have pushed the innovations toward the green economy. Innovation in customary processes led by sensors and intelligent systems have revolutionized in areas such as recycling cycles, product assembly, substitution of materials, and use of scarce raw materials." (Interviewee 11, 2021) |
| | Organizational innovation | 32 | "The green recovery depends on the position of companies and their responsibility in the production of renewable and clean energy… Companies and the government need to look at their processes and type of energy, and update their portfolio to enable other infrastructure sectors such as transport to revitalize their fleets of electric vehicles, powered by hydrogen and that could have the structure to enable the different types of innovation." (Interviewee 10, 2021) |
| | Product innovation | 30 | "Carbon offsetting is a solution that could help with the issue of climate change, capturing carbon. This considers the issuing of certifications and use of renewable energies that can foster sustainable consumption. The IoT and the cloud help a lot to monitor and create new products for the market in general, but we believe that blockchain is the next step for commercial exchanges of carbon between companies, especially in relation to the certification market… Not only startups, but large companies need to accompany the technological trend of the commercialization of energy and blockchain certificates, as well as monitoring solutions that already exist to reduce their carbon footprint." (Interviewee 12, 2021) |
| Emerging categories | Green spillovers | 16 | "... energy consumption in the general context influences various factors linked to infrastructure and local socioeconomic development when we look at the renewable energy grids…. for example, 80% of Brazil's grid is renewable and that makes the country competitive in terms of renewable resources, enabling it to explore energy development from an industrial viewpoint and access to clean energy… Here at the consultancy we see that the use of new technologies attracts investors to the energy sector, which stimulate the development of subsegments such as transmission lines, innovation ports and parks so that technologies such as offshore wind and hydrogen are made viable. That type of technological innovation is fundamental for energy transition and the regional development of emerging economies." (Interviewee 17, 2021) |
| | Technological sustainability | 28 | "The greatest sustainable innovation in technological terms is linked to the capacity to identify bottlenecks and consumer spending. For that we use sensors and monitoring via the IoT. We accompany the consumer's spending and we can reduce their energy expenditure, carbon emissions, and even indicate what the impact is that they failed to generate by carrying out their process optimization… Artificial intelligence and the IoT are very important for us, since it's an integration of resources of the computer programs that we use and the consultative practice… It seems complex, but to reduce the environmental impact via technological sustainability it's necessary to use the digital resources we have to guide entrepreneurs." (Interviewee 16, 2021) |

| | | |
|---|---|---|
| Digital leapfrogging to green technologies | 35 | "... the forecasting and monitoring systems work to predict the energy generation intervals, with a view to system optimization. Monitoring implies data management, using data analytics resources and artificial intelligence. The combination of these technologies enables better use of the assets of wind farms, giving large entrepreneurs digital mobility… The real monitoring of wind generation data, linked for example to energy constraints or intermittences of the systems, means entrepreneurs can assertively take routine decisions for the continuous development of their organization's asset portfolio." (Interviewee 15, 2021) |

Source: Elaborated by the authors.

Therefore, the categories that present the greatest relevance were process innovation, digital leapfrogging to clean technologies, and organizational innovation, which can be found in Figure 1, demonstrating predominance of the perception of innovation as a result of the entrepreneurs' actions. These categories are further examined in the triangulation of the reports and references from the literature in the sections below, thus addressing the gaps of Klewitz and Hansen (2014) and Cillo et al. (2019) and complementarily exploring the gaps of Ghorbel et al. (2021) and Aagaard et al. (2021).

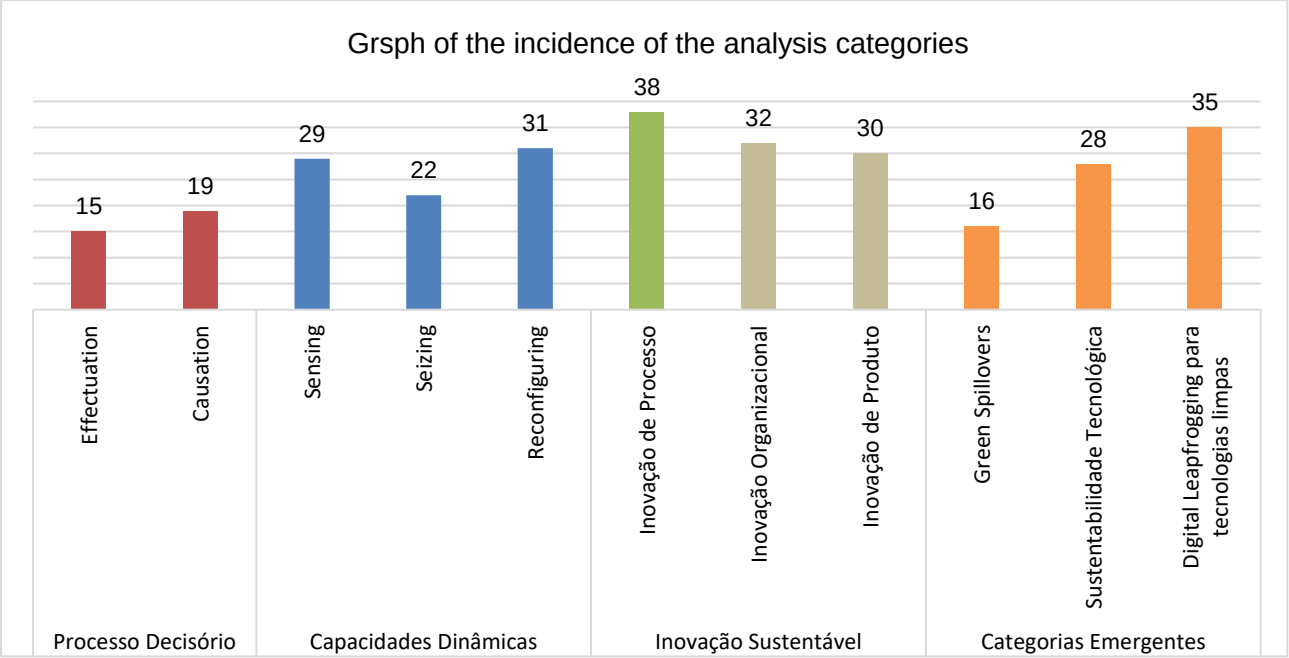


**Figure 4.** Relevance of the categories

Inovação de Processo: Process Innovation; Inovação Organizacional: Organizational Innovation; Inovação de Produto: Product Innovation; Sustentabilidade Tecnológica: Technological Innovation; Digital leapfrogging para tecnologias limpas: Digital leapfrogging to clean technologies; Processo Decisório: Decision-making process; Capacidades Dinâmicas: Dynamic Capabilities; Inovação Sustentável: Sustainable Innovation; Categorias Emergentes: Emerging Categories.

Source: Elaborated by the authors

## Decision-making process block: effectuation and causation

In the decision-making process block it is possible to find a lower incidence when compared to the other categories, due to the greater difficulty of measuring/perceiving that element. Nonetheless, the interviewees highlighted the entrepreneurial flexibility linked to the process of continuous improvement in the organizations, affecting the reorganization of company resources to promote innovation of a sustainable nature, thus fostering the establishment of networking for the development of innovation.

The **effectuation** category showed that the innovations of the cleantechs enable the entrepreneurs to apply their solutions at the organizational level, aiming to leverage the company's performance by reducing fixed costs based on previous commitments established in the planning of the business model. That planning involves the solutions of the cleantechs linked to energy

efficiency and to the use of renewable energies through commercialization, enabling a reduction in the organization's costs and giving mobility to the implementation of innovations with a lower impact on the environment, coordinated through the effectuation decision-making process (Interviewees 1 and 2). Consequently, the interviews highlight in the effectuation category that both (a) the entrepreneur's profile and (b) the network of contacts (Kalinic et al., 2014; Sarasvathy et al., 2008; Roach et al., 2016) drive the use of the dynamic capabilities of seizing and reconfiguring, in line with P1 of this article. In addition, entrepreneurial flexibility, which involves the reasoning guided by continuous improvement in the business models, contributes to prior commitments, which cover informal alliances and networks, where the dimension relates to the selection and commitment of the different interested parties among entrepreneurs that adopt cleantech solutions and innovations practiced by the companies (Barzotto & Nassif, 2019; Kalinic *et al.,* 2014; Sarasvathy, 2001).

In the **causation** category, in turn, it was observed that new technologies, such as the internet of things (IoT), big data, and data analytics, operated by cleantechs, enable the interviewees to reduce fixed costs and create new strategic planning perspectives. This was a point mentioned by Interviewee 3, who showed innovative solutions that accompany the movements of competitors and careful planning based on well-defined goals in the action plans of the business models. They develop long-term strategic projects aiming to minimize organizational costs via digitalization and the practicing of technology-based sustainable solutions (Kalinic et al., 2014; Sarasvathy, 2001; Sarasvathy et al., 2008). Therefore, it is possible to observe through the sematic analysis of the interviews that the causal logic favored the identification and generation of dynamic capabilities, supporting the sensing dimension (according to P2).

### Dynamic capabilities block

The dynamic capabilities block presented high relevance during the analyses of the transcriptions (Table 3) due to their intermediary nature for generating sustainable innovation, via the sensing, seizing, and reconfiguring categories. The interviewees showed that the entrepreneurial initiative and its decision-making process should include the capabilities of sensing, planning, and transforming the businesses so that the companies can explore technologies in a sustainable way.

From analyzing the data collected, the interpretation of the interviewees' speech leads to the understanding that the **sensing** category is strongly linked to the innovations that appropriate technologies, such as the IoT, big data, and the data cloud to generate sustainable solutions (Interviewee 5), based on solutions for monitoring energy and water consumption behavior, solutions for avoiding carbon emissions, solutions for capturing gases, and even the adoption of renewable energies, helping the global context of containing climate change and global social inclusion. These solutions are primarily developed from the entrepreneurial initiative of the decision-making process via effectuation. The reports linked to the sensing category for the context of the cleantechs are consistent with the existing literature presented by George et al. (2020) and Inigo et al. (2017).

The **seizing** category manifested as a transitory mechanism for allocating technological resources, aiming to obtain sustainable gains for the clean technology companies. Interviewee 7

highlights a consensus among the data gathered, indicating that natural resources are finite and organizations need to focus their technologies on digital solutions to complement the existing technologies, reducing cost, technology, and R&D bottlenecks. According to the reports, the seizing category manifests in the cleantechs for strategic restructuring of existing solutions, making the processes cleaner and more technological. Yet, due to the resources of the cleantechs being limited and them depending on high investments from investment funds and financial institutions, seizing is driven by the initiative of entrepreneurs that seek the incubation, acceleration, and funding process to restructure the resources and deepen technological knowledge to provide the market with innovative and sustainable solutions (Cillo et al., 2019; Cumming et al., 2016; Klewitz & Hansen, 2014).

**Reconfiguring** is presented as a contrasting trait for the structuring of sustainable business models from the socioenvironmental and competitive viewpoint in the organizational environment. The reports show that the cleantech business model should have flexibility for agile restructuring, keeping a focus on the regulatory environment of the infrastructure sectors (Interviewee 9). Topics such as decentralization of energy systems and autonomy for energy commercialization are fundamental for achieving the sustainability of individual solutions, at a competitive price, offered by businesses that adapt to environments with a complex regulatory framework (Inigo et al., 2017). On the other hand, cleantechs can also be considered as cogs in the reconfiguration toward innovation of major energy systems, modifying countries' transmission, generation, and energy distribution contexts. The entrepreneurial initiative via causation, targeting the final user in the context of providing solutions, reverberates in multiplying effects for the major infrastructure sectors, supported with technological solutions that, besides reducing costs, make the systems renewable, clean, and less environmentally impactful.

### Sustainable innovation block

The sustainable innovation block manifests in the research as the analysis block with the greatest repetition relevance (Table 3). The role of process innovation is latent for cleantech companies, and it is driven by the effectuation decision-making process. On the other hand, product innovation and organizational innovation are primarily driven by the sensing and reconfiguring of dynamic capabilities, which lead the company to adopt digital processes for reconfiguring its business models.

Process innovation was presented as the category with the greatest incidence in the study and is associated with creativity and speed in taking decisions based on the available resources. In this sense, the reports from most of the interviewees (e.g. Interviewees 11 and 16) identified that the use of new technologies – such as artificial intelligence, the IoT, and the cloud – are fundamental for absorbing the feedback from experimentation and remodeling the businesses to meet social and environmental demands from infrastructure-based sectors. This enables less use of natural resources and the application of those technologies to create solutions that monitor different types of consumption, reposition companies in their supply and logistics chains for a lower environmental impact, provide access to cheap energy for communities, and stimulate the creation of low-cost social projects via technology adoption in their solutions. These solutions applied by cleantechs bring medium- and long-term economic effects for society, the environment, and adjacent industries, reverberating in climate and environmental goals established by different governments.

In parallel, product innovation is also associated with the adoption of technologies that give the company digital mobility; however, the causation of the decision-making process plays the role in the systemic analysis process and realization of research that refines the product, giving support via the sensing and seizing categories of the dynamic capabilities. These technologies have enabled companies, customers, and their communication channels to draw closer, collaboratively building demands that enable the integration of energy systems based on renewable sources, driving consumption through certifications or energy offsetting systems by means of distributed generation or regulatory schemes (Interviewee 12). Therefore, technologies enable restructuring and product refinement by means of digital leapfrogging by cleantech companies.

Organizational innovation, in turn, is strongly associated with the reconfiguring of dynamic capabilities and is manifested in cleantechs in the process of adapting to the context of rapid technological change and to the uncertainties of the regulatory framework, supporting the organization with knowledge to remodel its routines. In addition, the technologies operated by the entrepreneurs enable corporate governance structures that directly influence the process innovation and product innovation. Interviewees 1 and 10 mention that, besides the use of artificial intelligence and cloud technologies, credit management provides the organization and customers with mobility to innovate in their business models (Brink, 2019; Inigo et al., 2017), enabling access to renewable energies, such as wind and solar, allowing for a reduction in energy consumption costs, and with monitoring at scale for the businesses themselves.

### Emerging categories block

The repeated categories found during the data analysis and that emerged beyond the theoretical framework are presented in the emerging categories block of this section and will be presented as research findings, consistent with the data analysis. These categories are: (a) green spillovers; (b) technological sustainability; and (c) digital leapfrogging to clean technologies.

Spillover effects are identified when the cleantechs appropriate clean and renewable production technologies with the support of investments from international funds. We say this phenomenon occurs in the **green spillovers** category, as it refers to the positive spillover effect caused by the clean technology solutions, causing social and economic development in infrastructure-based sectors such as energy, transport, and sanitation. This phenomenon has already been mapped in the literature in another context by Wang, Zhang, and Hu (2021) and Yoshino, Taghizadeh-Hesary, and Nakahigashi (2019). However, from the cleantech perspective, the investments made in this type of company collaborate in the transition of electric energy grids of countries, stimulating the installation of electrical energy, avoiding overconsumption of water through monitoring, and even mapping the precarious sanitation conditions in developing economies, as mentioned by Interviewee 17.

Category b, **technological sustainability**, involves the technologies that are chosen as a resource to foster sustainable development and political-regulatory alignment. According to Musango and Brent (2011), technological sustainability is understood as technological development, sustainable development, and system dynamics that operate to generate sustainable innovation in the businesses. For cleantechs, technological and digital integration enables the remodeling of routines and the creation of new products that drive sustainable and innovative

production in the companies. The environmental and social risks can be reduced via entrepreneurial solutions addressed by technologies such as artificial intelligence, the IoT, 5G, and the cloud (Interviewee 16).

The adoption of the technologies mentioned by the interviewees in the survey (Interviewee 15) means the company makes a digital leap in its routines and its market orientation present in category c, **digital leapfrogging**, to clean technologies. The concept of digital leapfrogging refers to the transformation of the digital innovation of companies, causing socioeconomic and industrial development (Estevez, Fillottrani, Linares Lejarraga, & Cledou, 2021; Tim, Cui, & Sheng, 2021). In the case of the cleantechs, digital leapfrogging also corroborates with the environmental and social inclusion dimension, reverberating in competitive advantages in the company's market segment.

## *Results and discussions*

The data analysis via analysis categories revealed some elementary results for fulfilling the research objective that will be presented in this section. These results refer to the incidence of the categories and how they relate with the literature, with the model of the decision-making process for the development of dynamic capabilities, with sustainable innovation, and with the fulfillment of the propositions. The results demonstrated that the analysis categories of the decision-making process and dynamic capabilities are mechanisms that enable the cleantechs to adopt new technologies to provide solutions of an innovative and sustainable nature.

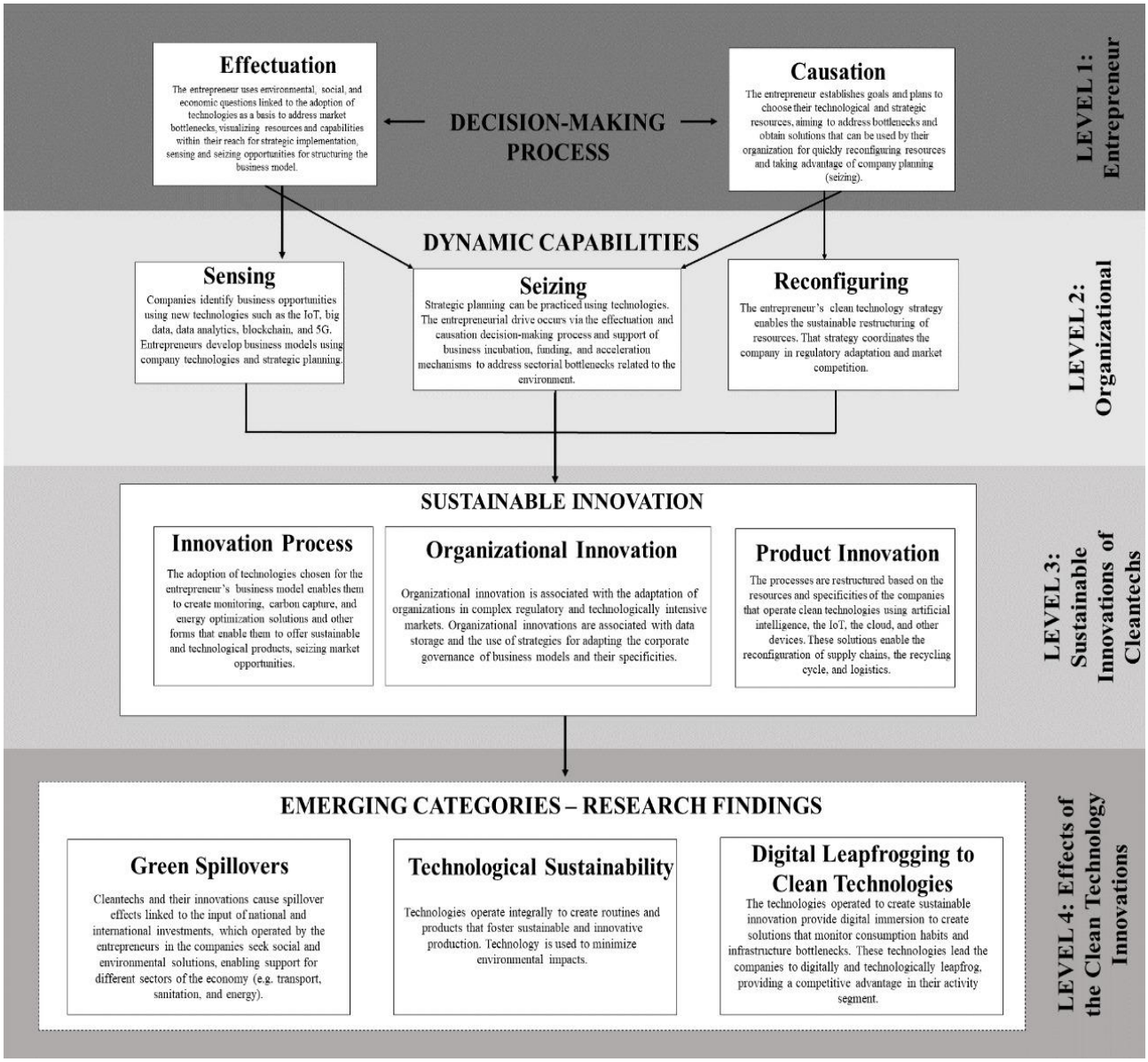


**Figure 5.** Model of decision-making process and the development of dynamic capabilities for generating sustainable innovation and its effects

Source: Elaborated by the authors

The categories explored in the research present a model that manifests their articulation between different levels, namely: (a) level 1: entrepreneur; (b) level 2: organizational; (c) level 3: sustainable innovations of the cleantechs; and (4) level 4: effects of clean technology innovations (Figure 3). In addition, each one of the levels presented reflects the categorical processes of data analysis. The model presents the association between the categories, illustrating how the decision-making process can develop dynamic capabilities for generating sustainable innovations, consistent with the objective outlined in the paper.

Moreover, the propositions were integrally fulfilled. P1 was confirmed, given that the entrepreneurial initiative via the decision-making process is associated with the categories of sensing opportunities and taking advantage of them to work its business models and generate

solutions of a procedural and organizational nature, incorporating technological and digital solutions for the business.

In addition, P2 was also confirmed, and, in this sense, the decision-making process using the causal logic is associated with the categories of seizing opportunities and reconfiguration at the organizational level, corroborating with product innovation and organizational innovation, especially of a technological nature, adding to business models solutions for reducing the carbon footprint in processes, products that do not impact the environment, and business optimizations of a sustainable nature that are especially associated with procedural increments, derived from the entrepreneurial decision-making, digitally leapfrogging to technological sustainability.

On the other hand, P3 was confirmed by finding that, despite the dynamic capabilities being worked through the decision-making process via confirmation of P1 and P2, the role of the organizational level is a guiding mechanism for generating sustainable innovation on the three fronts: process, product, and organization, as it involves the adoption of new technologies (e.g. the IoT, big data, blockchain, and 5G), mentioned during the course of the interviews. This is also confirmed by the way the companies adapt their business models to meet environmental and societal challenges. In addition, the organizational level is the intermediary path for effects on the economy and society, caused by cleantech solutions and presented in the research findings, such as green spillovers, technological sustainability, and digital leapfrogging to clean technologies – effects that are subsequent to the sustainable innovation operated by dynamic capabilities worked by means of the decision-making process in its respective levels of the model presented.

In addition, the research findings provide a new horizon for studies covering the theoretical lenses chosen (e.g. decision-making process, dynamic capabilities, and sustainable innovation), providing new paths for observing the analysis levels. However, the findings address the research gaps of the studies of Ghorbel et al. (2021) and Aagaard et al. (2021), highlighting that the capabilities of the organizations induced by particularities of the decision-making process via effectuation or causation can promote sustainable innovations with different approaches to the market, reinforcing the fulfillment of the objectives.

Consequently, the results obtained by means of fulfilling the propositions also closely converse with the research from the literature of Klewitz and Hansen (2014) and Cillo et al. (2019), presenting sustainable innovation as a driver of technological and digital effects that enables the company to address market bottlenecks of a socioenvironmental and economic nature, driving sectorial investments. These findings not only address the gaps presented but also open the door to researching the association with other technological contexts in the sector that are not directly linked to the research segment of cleantechs.

## Concluding remarks

This article presented a model that illustrates how the decision-making process can drive the development of dynamic capabilities for generating sustainable innovations, emphasizing the levels linked to the analysis categories. The model helps to answer the “how,” addressed by the research question, and the objective outlined by the studies.

In addition, the three propositions raised to test the theoretical construction were fulfilled (P1, P2, and P3), highlighting the conceptual relationship between the three theoretical foundations chosen to observe the phenomenon of clean technology companies. The research context and its analysis process enabled the identification of concepts beyond the theoretical framework: green spillovers, technological sustainability, and digital leapfrogging to clean technologies. These concepts should be interpreted as new research avenues for further examining how the clean technologies operationalized by cleantechs can cause economic impacts in the market and society.

In addition, the model presented can be observed by means of the inclusion of new theoretical lenses that were not considered for the present research, supporting new observations for the levels presented. From this perspective, the scientific contribution lies in addressing the gaps of Klewitz and Hansen (2014), Cillo et al. (2019), Ghorbel et al. (2021), and Aagaard et al. (2021), highlighting that organizations can restructure their business models and develop sustainable and technological innovations, making a digital leap to address bottlenecks related to energy rationing, social inclusion through monitoring technologies, access to low-cost clean and renewable energy, and other solutions presented throughout the interviews of this research.

Also in relation to the scientific contribution, it was found that certain organizations can be a vector for economic development, generating spillover effects of a sustainable nature (green spillovers) (Wang et al., 2021; Yoshino et al., 2019), through falling within the scope of investment funds and international investors. These characteristics derive especially from the entrepreneur's capabilities to operationalize technologies that enable digital leapfrogging to clean technologies, also addressing the gaps presented by Klewitz and Hansen (2014) and Cillo et al. (2019).

On the other hand, the practical contribution of the research lies in the research context. Cleantechs, as startups, are drivers of innovations and concentrate technological knowledge in a disperse way, resolving challenges of society and of the environment in a decentralized way. The present article demonstrates the organizational-innovative potential of that company model, serving as an innovation blueprint for entrepreneurs, governments, and universities that seek solutions for the sustainable development challenges and goals outlined by the UN (Sachs et al., 2021).

### *Suggestions and directions for future research and limitations of the research*

The limitations of the present research are related to two main points: (a) the context of choosing the multiple case study method; and (b) general characteristics of the sample. The multiple case method limits the scope of the research, as it restricts the selection of cases to the scope of the work chosen to further the research. Thus, it is suggested that, for future research, the proposed theoretical model can investigate other research phenomena beyond the cases and context addressed here. From the same perspective, the general characteristics of the sample meant that most of the cleantechs chosen focused on the energy and sanitation segment. For future research, it is suggested that the researchers choose cleantechs from different areas of activity, such as transport and construction.

As a suggestion and direction for future research, the researchers should delve deeper into understanding how the model presented can be applied to other organizational contexts. Specifically, the categories that emerged as findings should be the main propositional guides for

new research, as it was not possible to delve fully into the findings regarding (a) green spillovers, (b) technological sustainability, and (c) digital leapfrogging to clean technologies, due to the scope chosen for the research. According to the technological premises of case studies of Hafiz (2008), propositional paths are suggested in Table 4 so that researchers can delve deeper in future research and that emerged during the data analysis of the present research.

Table 4

**Suggestions for future research**

| Research path based on the findings | Suggestions for future research |
|---|---|
| Green spillovers | Identify how green spillovers generated by clean technologies can drive the development of society and industry; map the relevance of the green spillovers caused by cleantechs for the development of international commerce; understand how spillover effects can intermediate in the internationalization of cleantechs; analyze what the relationship is between different types of innovation and green spillovers. |
| Technological sustainability | Verify what the main technologies are that foster sustainability and sustainable development among cleantechs (e.g. big data, the IoT, artificial intelligence, blockchain); present the role of technological sustainability for the generation of capabilities and competences linked to innovation; understand how resources can be allocated for the generation of technological sustainability in organizations; identify the role of the entrepreneur and the decision-making process for the articulation of technological sustainability. |
| Digital leapfrogging to clean technologies | Understand how digital leapfrogging manifests in organizations that adopt clean technologies in their business models; evaluate the relationship between digital leapfrogging and organizational knowledge to produce sustainable innovation; verify how digital leapfrogging to clean technologies can accelerate the process of competitive advantage of companies in the market; map the main antecedents for digital leapfrogging of organizations focused on clean technologies. |

Source: Elaborated by the authors.

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## Conflict of interests

The authors state that there is no conflict of interests.

## Inclusive language

The authors use inclusive language that recognizes diversity, shows respect for all people, is sensitive to differences, and promotes equal opportunities.

## Authors' contributions

**First author**: conception of the idea, structuring of the research axes, writing of the introduction, theoretical framework, methodology, data analysis, results and discussions and concluding remarks, data collection and processing for carrying out the analyses.

**Second author**: conception of the idea, structuring of the research axes, writing of the introduction, theoretical framework, methodology, data analysis, results and discussions and concluding remarks, collaborated in the image editing process and full review of the text and consistency of the material.

**Third author**: conception of the idea, structuring of the research axes, writing of the introduction, theoretical framework, methodology, data analysis, results and discussions and concluding remarks, collaborated with the editing, formatting, and compliance with the norms required for submission.

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Appendix 1

**Interview script**

| | Category | References | Questions from the survey script |
|---|---|---|---|
| Decision-making process | Effectuation | Dew & Sarasvathy, 2007; Kalinic, Sarasvathy & Forza, 2014. | How do you think the decision-making process can help in seizing opportunities and developing capabilities and sustainable innovations? |
| | Causation | Sarasvathy, 2001; Garrido, Kretschmer, Vasconcellos, & Gonçalo, 2020; Harms, Alfert, Cheng, & Kraus, 2021. | How does your organization choose the appropriate means to take logical decisions visualizing its capabilities and sustainable innovations of the market? |
| Dynamic capabilities | Sensing | Brink, 2019; Garrido, Kretschmer, Vasconcellos, & Gonçalo, 2020; Inigo, Albareda, & Ritala, 2017; Teece, 2017, 2018; Teece, Pisano, & Shuen, 1997. | What mechanisms are used by your organization to identify business opportunities to generate sustainable innovations and new capabilities? |
| | Seizing | Brink, 2019; Garrido et al., 2020; Inigo et al., 2017; Teece, 2017, 2018; Teece et al., 1997. | How does your organization plan and implement its strategies in search of sustainable innovations in the cleantech business? |
| | Reconfiguring | Brink, 2019; Garrido et al., 2020; Inigo et al., 2017; Teece, 2017, 2018; Teece et al., 1997. | How does your organization adapt to the technological context, using its capabilities for creating sustainable innovations? |
| Sustainable innovation | Process Innovation | Cillo, Petruzzelli, Ardito, & Del Giudice, 2019; Gobble, 2012; Klewitz & Hansen, 2014) | Considering the decision-making of different management levels of your company and its capabilities, what are your organization's main strategies for procedural and sustainable innovation? |
| | Organizational Innovation | Boons & Lüdeke-Freund, 2013; George, Merrill, & Schillebeeckx, 2020; Klewitz & Hansen, 2014. | How does your company visualize organizational innovation from a sustainable viewpoint? Could you explain how that occurs in your company, considering its capabilities and the decision-making of the different management levels of your company? |
| | Product Innovation | George et al., 2020; Klewitz & Hansen, 2014 | How do you think that the decision-making and capabilities in your cleantech can foster product innovation? Cite examples of product innovation and how they manifest in your cleantech? |

| | |
|---|---|
| Additional questions | Would you like to mention any type of innovation, capacity, or decision-making that has not been mentioned during your interview? If so, mention some example or case experience. |

Source: Elaborated by the authors.