

# Green Innovation Ecosystems: An Exploratory Study of the Involved Actors



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**Abstract** This article employs an innovation ecosystem approach to green innovations to understand how actors participate in the development. Thus, using a qualitative approach, we studied four cases of firms that have developed green innovations to analyze how the innovation ecosystem affects the firm. Data was collected through in-depth interviews and it was content analyzed. Our findings show that many actors can constitute innovation ecosystems. The most mentioned ones are suppliers, consultants and experts, and universities. Our findings contribute to the literature on green innovation by providing solid notions of the innovation ecosystem's impact on firms.

**Keywords** Green innovation · Sustainability · Innovation ecosystem

## 1 Introduction and Theoretical Background

Developing innovations has become a major target for industries that aim to capture returns and become technology leaders [1]. Nevertheless, innovating often requires knowledge and resources that companies do not fully comprise, thus open innovation strategies that include external actors and entities can be of great help [2]. Indeed, innovation is a systemic process and, as such, it demands that interdependencies with other players are managed in order to successfully develop new products [3]. In addition, market maintenance and success of the innovation need accompanying changes in the environment that support its existence and increase functionality and, therefore, the value delivered [1]. That is, innovations need changes that support its existence in the market, such as the development of product parts from suppliers,

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partners for repair and remanufacture, and even governmental legislation changes [4]. To that end, firms have established networks of partners to enhance the breadth and depth of their inventions in innovation ecosystems [5]. Innovation ecosystems consist of a setting of multiple independent actors that jointly create value in an environment that simulates organic ecosystems where firms and other actors cooperate and compete [6, 7].

Adner and Kapoor [1] claim that the ecosystem construct helps to make interdependencies more explicit among the actors. The authors argue that the innovation ecosystem is structurally composed of the focal firm, the components of the ecosystem, the complementors (i.e., organizations that add value to the innovation of the focal firm), and the customer. Ritala and Almpanopoulou [7] and Oh et al. [8] highlight that the term “innovation ecosystem” has become popular in industry and academia. Additionally, [9] emphasizes the determining role of the institutions of innovation ecosystems. Institutions concern the routines, laws, and rules that constitute incentives and obstacles to innovation. In other words, they are the “rules of the game” [9]. Conceptually, several definitions of innovation ecosystem have been proposed (see [10]). Many theorists claim the innovation ecosystem’s concept’s birth belongs to [11], who proposed that a company can be viewed as a part of a business ecosystem that is not restricted to its geographical or sectoral boundaries and that is characterized by interdependence and coevolution of capabilities to increase value.

Considering the importance of innovation ecosystems in supporting and increasing the functionality of innovations, green innovation ecosystems (IEs) arise as an important topic of interest, since this green innovation demands a common joint effort from suppliers, universities, policymakers, users/customers, and complementors to succeed and make a change [12]. Green innovation entails the integration of sustainable elements into firms’ new or improved products, services, processes, or practices or the development of new ones that either reduce their environmental impact of the product, neutralize it, or even cause a positive impact [13, 14].

Interest on this topic has rapidly increased and [15] report that investments in environmentally sustainable innovation are expected to reach US\$10 trillion by 2020. Consequently, new markets allowing for many opportunities emerge, as well as new challenges that include changes in established markets and the need for support and participation of different actors and innovation ecosystem factors [16].

Therefore, understanding the link between the actors of this ecosystem is essential to become aware of ecosystems’ boundaries and impacts. Environmentally sustainable issues are acknowledged to generally fall beyond the core activities of most firms, and even some firms that wish to develop green products do not own the necessary resources [17], which further advocates for open innovation practices. Nevertheless, how actors’ dynamics occur in green IEs still remains an unanswered question in the environmentally sustainable innovation field.

Although some studies have recognized green innovation actors, they have either ignored the role of codevelopment and competition of actors within ecosystems, or they did not address the “whole picture” of the innovation ecosystem. For example, [18] only addressed how some stakeholders impact the research and development of green products and their findings only present the actors that are closest to the

company, such as universities, consultancies and non-governmental organizations. Melander [14] on the other hand only addresses the integration of suppliers and customer for green product innovation which narrows the open innovation process. The focus on supplier and customer integration hinders a more profound understanding that recognizes that firms that develop green innovations are found in deeper, more complex innovation settings formed by multiple actors that are not as closely coupled with firms.

Recognizing the actors that play a role in the development of green innovation is of utmost importance as firms rely on these actors' resources and expertise on green innovation to develop green products that are more efficient from the environmental point of view and that address market needs [14]. However, being able to establish ecosystems where actors are able to coevolve and jointly deliver marketable green innovations largely depends on the effective identification of which actors integrate green IEs and which actors could help in the development of green innovations by adding resources to the ecosystem.

Thus, based on the potential contribution of the innovation ecosystem theory to the understanding of the dynamics in green innovation, this article addresses the actors of green IEs. To that end, we analyzed four different cases of firms that have developed green innovations to define actors and dynamics of green IEs. We posit that green innovations differ from regular innovations and, therefore, they create different innovation ecosystems due to the need to consider sustainability aspects during the innovation process. Responding to the call from literature, it aims to understand how green IEs are organized based on the roles played by different ecosystem actors. As such, we analyze firms that have developed green innovations using open innovation practices to understand the green IEs.

The rest of the paper is organized as follows. Section 2 concerns the methods of this research. Section 3 presents the results. The paper ends with discussion and conclusions in Sect. 4 and Sect. 5, respectively.

## 2 Method

Since this article aims to comprehend how green IEs are structured, we decided to use a qualitative approach to the problem, in line with the study of [19]. Thus, we conducted in-depth case studies of four companies that develop green innovations and are located in Brazil. Data were collected mainly using semi-structured interviews to gain deeper insights on the actors and dynamics of the green IEs of each company, and it was complemented using published data sources from companies to enrich the findings [20]. The questionnaire contained nine questions that addressed green innovations, ecosystem structure and governance and the impact of the ecosystem on the firm. To guarantee anonymity, firms were assigned codenames (Tractor, Heath simulation, Fashion retail, and Grain drying) and a brief description of each firm is presented next.

**Table 1** Information about the cases studied

Codename	Size	Interviewee	Innovation description
Tractor	Large	Head of Product Engineering	Tractor with controlled residual emission
Health Simulation	Startup	CEO/Founder	Devices and products for health simulation such as vials, gels, and dummies
Fashion retail	Large	Sustainability Analyst	Development of a sustainable chain of fashion retail to promote green raw materials and processes
Grain drying	Startup	CEO/Founder	Development of sustainable grain drying system that eliminates current highly polluting heat sources

The company under the Tractor codename refers to one of the biggest tractor manufacturers in the world. The company has developed a low-emission tractor engine to comply with new regulations that demand the reduction of polluting gases. Health simulation is a startup that develops environmentally sustainable solutions for the simulation of health procedures for medicine and nurse students. During the development and commercialization of the products, actors had to be involved, since the company did not have all the resources and knowledge to develop and market the products. Fashion retail is the case of a major fashion Brazilian garment company. The company does not produce the clothes, rather, it just sells them, therefore, it had to engage stakeholders to create more sustainable products and greener operation. The Grain Drying case refers to a startup that has developed a greener solution to dry grains stored in silos. Table 1 summarizes the information about each case.

Interviews lasted around 75 min each and were recorded and transcribed. Transcripts were content analyzed using a coding technique to divide relevant content of transcripts into categories, as also done in the qualitative paper of [19]. After coding, we performed within cases and cross-case analyses following [21].

### 3 Results

A deeper understanding of the innovation ecosystem and its dynamics can only be achieved through the understanding of the actors that compose the green IEs. In this regard, our analysis shows that several are the actors play a role in green IEs. The most referenced actors are suppliers, since they directly influence the performance of the development, production, and commercialization of products. In the case of the *Tractor* firm, suppliers were included during the design of the parts of the tractor, in order to assist with the technology and the requirements necessary to allow the engine to reduce particle emission. In other cases, suppliers are responsible for the entire pool

of sustainable attributes of the final product. This is the case, for example, of *Fashion Retail*, where the focal firm does not manufacture the products; nevertheless, *Fashion Retail* enforces sustainable practices for suppliers to assure that the final product is in line with the sustainable values.

We develop suppliers to make them sustainable. We made them aware of sustainability and then we showed them how to reduce waste. (...) The first step was to promote knowledge about the importance and the impact of being sustainable and of adopting sustainable practices. We hired consultancies for the suppliers to give them knowledge about how to be sustainable and to optimize the cutting of the pieces, to diminish waste and to reduce consumption.

(Sustainability Analyst, Fashion Retail)

Developing sustainable innovations is not a trivial task for firms, which usually lack the resources to do that. Hence, firms integrate consultancies and experts in their innovation network. Consultancies and experts span the boundary between the knowledge internally diffused and the knowledge externally available, which is not always entirely at firms' reach. Therefore, through consultancies and experts, firms can acquire knowledge related to green innovations even though the firm did not hold the entire necessary knowledge and capabilities for that. Nevertheless, it is important that firms have the necessary means to exploit the knowledge absorbed, otherwise, they may not be able to fully leverage it. The *Grain Drying* firm highlighted the lack of such mechanisms to leverage the external knowledge acquired since the startup collaborated with experts to help develop a marketable solution, but they failed to exploit it to the fullest. This is evident in their quotation:

We were not able to do that internally. So, the practice we adopted was to have partnerships, agreements with companies that had this know-how. (...) We sought partners who gave us the technical support about an area of knowledge that we did not have. (...) So we have always looked for representative entities that had these competences, but we did not internalize the knowledge. And that was one of the pains of our project, now we see that this was a mistake...not having this intellectual capital inside the company.

(CEO/Founder, Grain Drying Case)

The third most mentioned actor in the green IEs is the university. Universities were reported by respondents to be knowledge-rich environments where information can be achieved to improve the innovation process of firms. The *Fashion Retail* firm, for example, partnered with universities to conduct life cycle assessment of products, whereas the *Health Engineering* firm collaborated with the pharmaceutical labs of a major university to help develop its simulation products using the know-how of experts. Additionally, the *Tractor* firm required specialized laboratory tests to measure emissions and particle counting during the development of its tractor. Thus, the firm hired universities to conduct the tests and analyses in their laboratories given universities' structure and know-how of researchers.

Our findings show that Research and Technology Firms participate in the design and prototyping of products. For example, the *Tractor* firm hired technology firms to assist in the design of the new engines. According to the interviewee, partnering with technology firms is ideal for technology-related R&D issues that the focal firm is not able to handle alone, since this type of firm holds great expertise in technology

development and implementation. Whereas the *Grain Drying* firm partnered with research laboratories that assisted in the testing of the solution and in measuring the results achieved during the validation of the prototypes developed. Mostly, according to the interviews, this type of actor is included in the ecosystem because of its advanced knowledge and resources to design, measure, and test solutions that will influence the innovation developed.

Complementors are the next most mentioned actors in the innovation ecosystems analyzed. Complementors, as previously defined, are actors responsible for adding value to the innovation ecosystem; however, they are not the focal firm's suppliers or direct actors. This does not mean that their role can be neglected when analyzing green IEs. The case of the *Tractor* firm is a good illustration of that. During the development of the tractor with reduced emissions, oil and gas companies were included because the new engines required fuels with specific chemical characteristics (i.e., reduced particles). Oil and gas companies had to develop new processes and systems that allowed the production of this type of fuel so that, when the tractor reached the market, the necessary asset network was ready to support its operation. The quotation presented below highlights the role of the complementor to the innovation of the *Tractor* firm:

The oil companies had to make diesel fuels with less quantity (of particles) that forced them to have more technological refining plants, more novel processes. (...) the agricultural machinery manufacturers had to develop their machines to receive these engines. The oil companies had to make better diesel. The exhaust systems had to be improved. The diesel filtration systems had to be improved, the systems of air filtration had to be improved (...), electronic equipment was more widely used in the machines.

(Head of Product Engineering, Tractor case)

Additionally, we found that class organizations also participate in the innovation ecosystem. The *Fashion Retail* firm participates in a class organization specific for fashion firms. Through the knowledge acquired by collaborating with such an organization, the *Fashion Firm* was able to develop a sustainability standard to which its products comply and carry a label. The *Health Engineering* firm also consulted class organizations to acquire knowledge related to the regulations of the health simulation and health education sector.

Other actors in the innovation ecosystem are investors and shareholders. This was observed in the case of the *Fashion Retail*, which is a publicly-traded company that is pushed by shareholders to adopt green practices. According to the interviewee, although customers' demand for green products in Brazil is still below expected, in Europe and North America such concern is more widespread and fashion retail firms are pushed to adopt green practices and market more sustainable products. Thus, investors and shareholders press the firm to hold the same standards in Brazil.

It is important to highlight the relevant role played by regulation agencies in green IEs: they are responsible for creating policies that can enforce firms to innovate and can impact the development of the innovation. This is highlighted by the interviewee from the *Tractor* firm, which explains that the innovation developed by the firm underwent tests from the regulatory agencies to guarantee the tractor complied with the legislation on emissions.

Additionally, interviewees also reported the role played by the government in policymaking and law creation. For example, the *Health Simulation* firm developed sustainable simulation products to meet a market demand generated by a governmental law, which required health-related undergraduate courses to maintain simulation laboratories for student practice. The innovation in the *Tractor* firm was also triggered by a law that required engines to reduce the number of particles emitted in fuel burning. Nevertheless, the need for a greater incentive by the government to require environmentally sustainable practices from all the players in the market was observed. Interviewees reported that the government should push for more sustainable operations from all manufacturers, as, according to them, developing and marketing sustainable innovations can be more expensive and costly. Thus, interviewees state that as they develop green innovations, the government should require the same from competitors in order to even market competition under green conditions.

We also found that coworking spaces, innovation hubs, and incubators play a role in developing knowledge for innovation of firms. For example, the *Grain Drying* firm and the *Health Engineering* firm participated in a University's incubation program to develop marketable products and management skills. Most recently, the *Grain Drying* firm has joined a coworking space to improve its network of partners. Additionally, although such spaces and programs are more directed to startups and small firms, we found that the *Fashion Retail* firm developed a startup acceleration program to accelerate startups focused on green innovation to possibly develop new suppliers and partners.

Finally, customers play a major role in the environmentally sustainable innovation ecosystem of firms. Although the notion that the demand for sustainable products is still not as high as would be expected, firms integrate customers during the development process in order to assure that the product meets the demands and that it is aligned with the needs. This is highlighted in the following excerpt of the CEO and Founder of the *Grain Drying* firm:

Interacting with the customer (...) this ecosystem must take you directly to the customer, to validate the solution with the customer. First, you do the back-office work, then you go back to the drawing board to develop the product.

(CEO/Founder, Grain Drying Case)

Table 2 presents each actor mapped in our study, along with the number of references to the actor in the interviews and an illustrative quotation. It is important to highlight that the reference count refers to the number of different excerpts that addressed the actor and not the word count for the actor, similar to the approach used in de Medeiros [22].

**Table 2** Actors, references and quotations

Actor	#	Illustrative quotation
Supplier	20	We started to promote supplier awareness about the importance and impact of being sustainable and of adopting sustainable practices. To that end, we paid consultancies to suppliers to provide information about how to be sustainable and to optimize the cutting of parts. (Fashion Retail)
Consultancies and experts	10	(...) the specialists, the experts. They were important for me to get where I needed to be. For example, in the third product, the gel, I do not understand anything about gel, so I went to a compounding pharmacy and I talked to the pharmacist. (...) I am in the prototyping phase, so I need the dealer, I need the expert, I need the supplier (Health Simulation)
Universities	9	The university is a very knowledge-fertile environment because in it I can easily find the experts that I need. Therefore, inside the university, I find the experts (...) to start a work of creation. (Health Simulation)
Research and technology firms	4	Another company is AVL. They do research in the field of engine technology, research, work and projects on this area (Tractor)
Complementors	4	The oil companies had to make diesel fuels with less quantity (of particles) that forced them to have more technological refining plants, more novel processes. (Tractor)
Class Organization	4	We involved class organizations formed by representatives of the textile retail sector. Through this class organization, we were even able to develop a standard (Fashion Retail)
Investors and shareholders	3	Sustainability within Fashion Retail comes from two main reasons: the customer asks for more and more sustainable practices and products. But a lot is due to the shareholders, mainly those from Europe and North America, and our administrative board. The shareholders of developed countries already have this concern in their countries, so they demand us to have the same concern for sustainability here. (Fashion Retail)
Regulation Agencies	2	Organizations have been created, for example, in the USA, they have the Environmental Protection Agency, there is ACABI, I think it's from California too (...) here in Brazil we have IBAMA (Tractor)
Governments	2	Health simulation is an emerging market in Brazil; it generates millions in the world. In other countries, this market (of health simulation) is very powerful, why is that? Because the student cannot touch patients before graduating. So the student goes through the whole course doing a lot of simulation. It is a legal issue. Our Brazilian curriculum still does not require this, but there is practically no health undergraduate course without simulation nowadays. (Health Engineering)

(continued)



**Table 2** (continued)

Actor	#	Illustrative quotation
Coworking spaces, innovation hubs, and incubators	2	Recently I have joined one of these innovation hubs (...). It is a coworking space, but with a different proposal. It is not simply the leasing of a desk. I think that's what's making the difference. They provide you with some support. (Grain drying)
Other actors	2	We also involved startups. The idea was not to make them become our suppliers; our intention is to understand what they are doing so maybe one day they can become our suppliers in areas of support (Fashion Retail)
Customers	2	I need my customers, their opinion is very important; I am prototyping now, so I am testing the gel with customers. (Health Simulation)

## 4 Discussion

As discussed earlier, our study employed the innovation ecosystem theory to analyze how green innovations are developed by firms. As an open innovation approach, innovation ecosystem theory supports the notion that innovations are created from a “dialog with multiple constituents” [7]. Thus, our findings show that the alignment of values between actors is of paramount importance to any green IEs. Additionally, values must not only address the innovation itself, but also sustainability. Similar findings have been previously provided by Chen and Liu [23].

Our findings are in accordance with the work by Tsujimoto et al. [24], which is focused on discussing how actors' differing beliefs and values in the innovation ecosystem may cause unintended results at the ecosystem level. In fact, we found that firms must choose actors with similar values to be able to successfully exploit the innovation, otherwise, as the innovation process advances, such misalignment will lead to unsatisfying outcomes. To ensure the alignment with suppliers, for example, we found that firms can train them and provide consultancies. This leads to closer ties and better collaborative relationships between actors.

Additionally, using the open innovation view of green IEs, we found that some actors play a key role in adding or increasing the sustainability of the innovation. Suppliers can partly add sustainability to the final product (such as new engine parts in *Tractor*) or they can be responsible for the entire sustainability addition to the product (such as raw materials in the *Fashion Retail*). Universities can add sustainability to innovation through intellectual capital. We also found that some actors are more responsible for increasing the value of innovation, such as the complementors, but they can also be responsible for increasing sustainability. Thus, our findings are in line with results by Farla et al. [25], which highlighted the role of policymakers, customers, and other actors in the transition for sustainable societies.

## 5 Conclusions

This research has addressed the actors of environmentally sustainable innovation ecosystems. Our findings show that the constituents of the ecosystem play an important role in adding sustainability to the green IEs. The contribution of this article to the literature on green innovation and on innovation ecosystems theory is twofold. First, we provide a mapping of the actors of green IEs and provide a description of the role played by them. To date, although studies on green innovation have recognized the role of inbound open innovation [26], authors have not provided an in-depth description of the actors that impact the green innovation development and commercialization and, most importantly, the roles played by such actors, under the innovation ecosystem perspective.

Nevertheless, some limitations should be highlighted. First, we only address outbound-in dynamics of open innovation, and we do not study the dynamics of firms' internal knowledge that crosses boundaries to impact the ecosystem (that is, inbound-out dynamics). Thus, future research could study how firms developing and commercializing green innovations impact the other actors from the IEs through, for example, knowledge spillover that is absorbed into actors' boundaries. Moreover, future research could quantitatively study the impact of different types of actors and green IEs configurations of the outputs of innovation. More importantly, future studies can address how external resources from the ecosystem impact green IEs and how such resources are orchestrated within firms.

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