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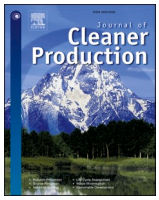

Green innovation networks: A research agenda

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ABSTRACT

Much of green innovation is the outcome of different levels of collaboration between organizations in different constellations. There is significant knowledge of interorganizational networks on the one hand and on green innovation on the other. However, less is known of interorganizational networks aimed at green innovations. The purpose of the paper is to develop a research agenda for future studies in green innovation networks. Extant literature on collaborations in networks to develop green innovations is reviewed. The Scopus database was used, with a search resulting in 63 papers. The review included a wide range of green innovations: products, services, processes, business models and marketing. Different types of actors and their reasons for engagement, the extent of networks and the prevalence of different actors were all identified. This research discusses what kind of network relationships (e.g. new types or cross-sectoral) need to be understood when studying these green innovations. Three areas for future research directions are proposed: the potential of horizontal collaborations in green innovation networks, cross-sectoral (including public-private) partnerships in green innovation networks and users as actors in green innovation networks.

1. Introduction

Today, our society is facing numerous environmental challenges caused by a growing population, rising industrial production and increased consumption. There is growing interest in the area of green innovation, which is evolving as new technologies and materials become available (Karttunen et al., 2021; Zhang et al., 2020). This paper takes a broad view on green innovation, considering any innovations that reduce the negative environmental impact of actors' businesses (Bocken et al., 2014; Melander, 2017). These green innovations can include products, services, processes, business models and/or marketing efforts. Hence, green innovation involves a wide range of efforts for improving environmental sustainability, sometimes also called eco-innovation. When developing new green innovations, firms need to collaborate to access knowledge, and as green innovations often involve new technologies and knowledge, they may need to search beyond their regular network of collaborators (Melander and Pazirandeh, 2019) and national and regional borders (Gunasekaran et al., 2001). As the need for new green solutions and expectations for rapid market introduction increase, it is difficult for firms to access all the required competences for green innovation in-house. Hence, firms seek to collaborate with actors that have knowledge and competences that complement their own. Green innovation tends to require additional competences, such as those within, e.g., new green technologies and new green regulations. Hence, multiple actors collaborate in networks to develop green innovations. Being part of a green network enable firms to incorporate new concepts, knowledge and practices for improved sustainability (Rossignoli and Lionzo, 2018). However, it is not clear what types of actors are included in green innovation networks, what their roles are and how they collaborate.

This paper combines two topics: interorganizational networks and green innovation. The first is vast, and there is a large body of literature on interorganizational network collaborations from multiple theoretical perspectives; these include the Industrial Network Approach (INA), which focuses on actors, resources and activities in business networks (Snehota and Håkansson, 1995), the knowledge-based theory of the firm (Grant and Baden Fuller, 2004), institutional theory (Scott, 2013), social embeddedness (Granovetter, 1985), managing alliances (Duysters et al., 1999) and open innovation (Chesbrough, 2003) to mention a few. Provan et al. (2007) point out that although research on interorganizational networks spans multiple research fields, it has common themes, which include "social interaction (of individuals acting on behalf of their organizations), relationships, connectedness, collaboration, collective action, trust, and cooperation". Interorganizational network research

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focusing on innovation includes multiple types of networks (e.g. cross-sectoral, horizontal and vertical), aspects of these networks, contemporary actors within the networks and potential success factors, the relevance of which for green innovation we explore in this study. Green innovation, on the other hand, has only received significant attention in recent years. A number of literature reviews have been conducted focusing on different aspects of green innovation, such as drivers (Díaz-García et al., 2015; Hojnik and Ruzzier, 2016) and benefits of the implementation of green innovation (Karimi Takalo et al., 2021).

The combination of green innovation and collaboration has been explored in a number of literature reviews. Dangelico (2016) investigates success factors for green product innovation and points out the importance of managing collaborations with external actors. Focusing also on green product innovation, Melander (2017) shows that the most common approach is to collaborate with suppliers, customers, and universities and research institutes. A recent review analyses the why, what, how, who, how much, where and when of firms collaborations in green innovation (Pereira et al., 2020). The authors point to governments, universities and research institutes as being particularly important, highlighting the public-private collaboration of green innovation. Although these reviews highlight several different external actors with whom firms collaborate in green innovation, they mostly take a dyadic approach, focusing on how firms collaborate with, e.g., suppliers in one way and universities in another. Therefore, there is limited insight from these reviews on how firms engage in green innovation within a network of multiple actors, what works and what does not, the barriers and drivers of such collaborations and the possible outcomes.

Hence, while there is a significant base of knowledge on interorganizational networks on the one hand and green innovation on the other, less is known of interorganizational networks aimed at green innovations. Thus, this study reviews extant literature on collaborations in networks for developing green innovations to extend our understanding of their nuances and complexities. The purpose of the paper is to develop a research agenda for future studies in green innovation networks. Through the review we: (i) identify the actors involved in green innovation networks and the roles they play in them, (ii) seek to understand how and why actors collaborate in networks and (iii) explore the challenges they need to overcome for successful collaboration in green networks.

The paper reviews literature on interorganizational networks aimed at green innovations and identifies potential areas for future research. The paper contributes three future potential research directions: horizontal collaborations in green innovation networks, cross-sectoral partnerships in green innovation networks and users as actors in green innovation networks.

The paper is structured as follows. First our method is described. This is followed by a descriptive analysis and then a network analysis. Finally, a discussion and conclusions are provided, including suggestions for future research directions.

2. Method

We opted to use Scopus as it is a comprehensive database for scholarly publications. There are several databases available, but Scopus is the largest abstract and citation database of peer-reviewed literature covering the humanities and social sciences. When conducting literature reviews, the criteria for inclusion and exclusion need to be specified (Fink, 2013). We performed a structured keyword search using title, abstract or keywords. We used three sets of keywords: (i) 'green' OR 'eco' OR 'environmental sustainable', (ii) 'innovation' and (iii) 'network', which resulted in 862 documents. The keywords were chosen to ensure the inclusion of relevant articles. The first set of keywords (i) was viewed as being sufficiently inclusive, comprising three often interchangeable words commonly found in the literature. This can be compared with other reviews focused on green innovation; Pereira et al. (2020) use only combinations of the word 'eco', while Dangelico (2016) combines a number of keywords including 'eco', 'green', 'sustainable', 'environmentally friendly' and 'environmental'. The second keyword (ii) chosen was 'innovation'; there are many other words that could have been included, such as 'product development', 'technology development', 'R&D' and so on. However, from looking at titles, abstracts and keywords while conducting our search, we believe that 'innovation' is the most commonly used term, although titles often include 'product development'. The third keyword (iii) chosen was 'network'; we did not include, for instance, 'supply chain collaboration' to exclude the vast number of papers that focus solely on single buyer-supplier relationships. Our aim was to have a clear network focus.

We chose to limit our search by only including articles (e.g. not book chapters) written in English. Since our focus is collaborations in networks, taking an organizational interest, we limited our search to only include publications within business, management and accounting (as defined by Scopus). These subject areas include journals that combine organizational issues related to innovation (such as Technovation), organizational issues related to innovation and sustainability (such as Journal of Cleaner Production) and marketing journals that cover network aspects in innovation (such as Industrial Marketing Management). This resulted in 137 documents. No specific start date was chosen. The first article identified was published in 1998 (Conway and Steward, 1998). All abstracts were read to ensure the content of the articles was relevant to the study. After reading the abstracts, 71 papers were found to fit our criteria for inclusion in the review. Papers were eliminated if they did not include a network of collaborating actors or cover the topic of green innovation. We then read the remaining papers in their entirety, whereafter eight were eliminated due to them not including discussions about collaboration, green innovation or networks. Hence, the final review consisted of 63 papers. See Appendix A for a list of the papers included in the review. Fig. 1 shows the process of our literature search and analysis.

A content analysis of the papers was conducted, whereby the papers were coded and categorized (Schreier, 2014). An initial categorization consisted of coding the papers according to their methods used (qualitative, quantitative, mixed method, literature review and conceptual paper), the type of green innovation studied (product, service, process, business model, material, technology, combination of innovations, other), geographical region of the study (single country, multiple countries, regions, worldwide, not specified), theory focus (innovation focus, network focus, sustainability focus, supply chain management focus, multiple, other), number of actors in the network, type of actors

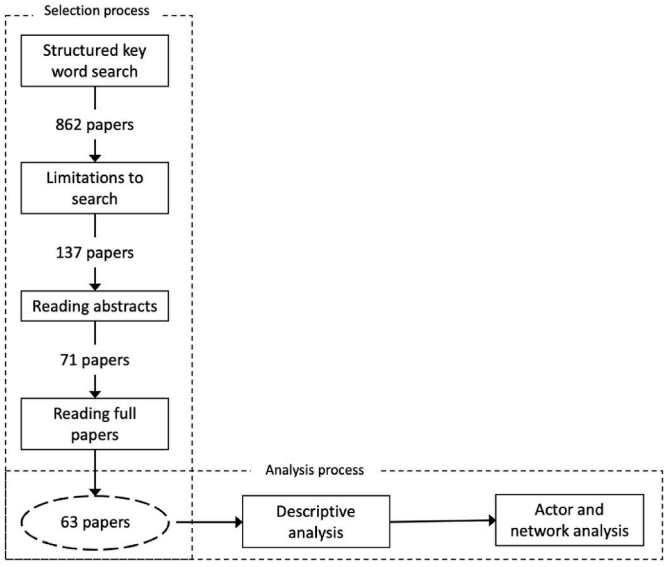

Fig. 1. The process of our literature search and analysis.

(buyer, supplier, competitors, academia, research institutions, government, intermediaries, trade associations, consultant, non-governmental organizations [NGOs], other) and networks included (network constellations, supply chain, alliances, cluster, partnerships, not specified), content of the collaborations (technology, materials, product developments, implementations, testing, commercialization, organizational developments, other), types of relationships (close, semi-close, semi-distant, arm's length), and level of collaboration networks (micro, meso, macro) discussed. The first part of the descriptive analysis focused on the methodology used, geographical region, industry studied and journal of publication. This analysis was conducted to provide an overview of the type of papers included in the review, i.e. the methods applied and where (geographically and industry) the studies were carried out. This contributes to the understanding of the next part of the descriptive analysis: explaining the types of innovations, networks and collaboration partners studied in the reviewed papers.

We analysed each paper using our framework, which focuses on the kind of network relationships (e.g. new types or cross-sectoral) that need to be understood in studying these green innovations. This framework consists of actors, roles and interactions (see Table 1). We focused on why actors engage and the roles they play in the networks, the extent of networks and how the included actors interact. These elements are in line with other network-focused studies, pointing to the importance of actors, roles and interactions (Bankvall et al., 2017; Jocevski et al., 2020). The raw data from the articles were sorted in mega matrices (Miles and Huberman, 1984) to enable a structured comparison according to our constructs. The actor analysis was conducted by identifying and sorting data into topics such as types of actors, reasons for actors to collaborate, roles of actors and prevalence of actors. The network analysis was conducted by applying topics such as the extent of networks, network complexities, sharing of resources and shared activities within networks.

3. Descriptive analysis

First, the descriptive analysis presents basic information about the methods and empirical contexts to show the diversity of the methods applied and where the studies have been carried out. Table 2 presents the methods and the empirical contexts, i.e. the geographical areas and industrial settings. To provide further understanding of the types of papers included in the review, Table 3 shows the type of innovation, type of networks and number of collaboration partners.

The most common innovation studied is green product innovation (also referred to as eco-innovation, the development of sustainable new products and low-carbon innovation), which is studied in 22 papers. Following this is combinations of multiple green innovations, studied in 17 papers. These include multiple types of combinations of innovations, such as eco-design and product innovation (2), product and process innovation (7), product and service innovation (2), product, process and organizational/management innovation (2), management innovation and technology innovation (1), product, process, organizational and marketing innovation (1) and multiple types of innovations such as product, process, service, remanufacturing and digitalization (2). The third most common innovation type studied is material and technology innovation, also referred to as clean technology developments, sustainable technologies, eco-friendly materials and technologies, green technologies and energy-efficient technologies, which is studied in 12 papers. After this are green business model innovation (2) and process innovations (2). The remaining eight papers consist of a number of different green innovations, such as eco-efficient product-service systems (PSS), eco-industrial development, eco design, green marketing innovation, green patents, green practices, renewable energy and sustainable innovation in house building.

Most of the papers use the term 'networks' (42) or variations of 'supply networks' (13), such as 'supply chain networks', 'collaborations' or 'supply chain partners'. Two papers study alliances. The remaining six papers include green building stakeholders, platforms, R&D cooperation and regional collaborations. Within these networks, a number of different types of actors are studied. In seven papers, only one type of actor is studied, for example a network of suppliers, a network of stakeholders or a network of large companies. In 13 papers, two different types of actors are studied, such as a network of customers and suppliers, a network of supermarkets and agri-food actors, or innovative firms and incumbent firms. In five papers, three types of actors are studied, such as a network of research institutes, agencies and universities, or universities, research centres and private firms. Only one paper includes four types of actors in a network, namely suppliers, customers, partners and horizontal collaboration partners. The largest group of papers includes five or more different types of actors in a network, such as suppliers, competitors, consumers, research institutes, environmental protection agencies, media, local residents, private firms, end-users, energy suppliers, network operators, electrical equipment manufacturers, consultants, IT companies, research institutes, grid operators, governments, companies, universities and governmental agencies. In 16 papers, the types of actors in the networks are not specified.

A wide range of journals publish research on green innovation networks; one journal in particular appears often, namely the Journal of Cleaner Production, which published 23 of the articles studies. The next most common journal is Business Strategy and the Environment, which published six of the articles, and the third is the European Journal of Innovation Management, which published three of the articles. Two

Table 1
Constructs guiding the analysis developed from industrial network theory; see Bankvall et al. (2017), Jocevski et al. (2020) and (Laage-Hellman et al., 2014).

Actors	Roles	Interactions
Who?	What role?	With whom?
What characteristics?	When are they involved?	What resources and knowledge are shared?
Why are they involved?	Where are they involved?	Which coordination activities?

Table 2
Descriptive analysis related to method and empirical contexts.

Methods used	Geographical area	Industry studied
Qualitative (27, 43%)	Single country (47, 75%)	Manufacturing (14, 22%)
Quantitative (23, 37%)	Multiple countries (7, 11%)	Maritime and offshore industry (7, 11%)
Literature review (5, 8%)	A region, such as Europe (5, 8%)	Construction industry (3, 5%)
Mixed method (4, 6%)	Not specified, not applicable (4, 6%)	Energy sector (3, 5%)
Other, such as Delphi method, conceptual and Evolutionary-game model (4, 6%)		Other (18, 29%) Not applied or not specified (18, 29%)

Table 3
Descriptive analysis related to innovation and networks.

Type of innovation	Type of networks (as defined by authors)	Number and different types of collaboration partners
Product innovation (22)	Networks (42)	One type (7)
Combination of innovations (17)	Supply networks (13)	Two types (13)
		Three types (5)
Material and technology innovation (12)	Alliance (2)	Four types (1)
Business model innovation (2)		Five types or more (21)
Process innovation (2)	Other (6)	Not specified (16)
Other innovations (8)		

journals have each published two of the articles, Industrial Marketing Management and the International Journal of Innovation and Sustainable Development. The remaining papers are published in separate journals. See Table 4 for an overview of the journals most used as outlets.

4. Analysis

4.1. Typical green innovation network actors and types

The analysis shows a wide range of actors in green innovation networks that are also found in regular innovation networks, such as suppliers, customers, end-users, competitors, universities, research institutes, governments and policymakers. However, we found greater involvement by governmental agencies, regulators and policymakers in green innovation networks (see e.g. Garcia et al., 2019) compared to regular innovation networks. In addition, green innovation networks include actors such as environmental NGOs (Ceschin, 2013; Dangelico, 2016) and trade associations (Melander and Pazirandeh, 2019). Examples of environmental NGOs are organizations such as Greenpeace, the Natural Step and the Environmental Defence Fund (Stafford et al., 2000). Studies also show collaboration between actors through support platforms, by which, for example, start-ups and inventors join networks (Lubango, 2020; Pakura, 2020). A recent study shows that firms involved in green innovation tend to collaborate with a more diverse set of actors than those involved in regular innovations (Christensen et al., 2019).

It is suggested that the scope of green networks should include multiple actors that form a strategic network, including those from industry, government and research institutes (Planko et al., 2017). A recent study shows that firms use their extended network, such as their suppliers' and customers' networks in other industries, to gain knowledge for green innovation (Melander and Pazirandeh, 2019). Hence, firms use horizontal collaboration patterns in their green efforts, thereby looking beyond their traditional network partners. The structure of the network is important. Fusillo et al. (2020) show that firms tend to choose their collaboration partners based on trust and are more likely to collaborate when they already share a common partner. Within networks, it is shown that important collaborations take place on a frequent basis and that these persist throughout the green innovation process (Kiefer et al., 2017).

Pakura (2020) points out that start-ups tend to collaborate with other start-ups in networks, sharing knowledge with a give-and-take mentality. This is also the case for situations in which they are competitors. Wicki and Hansen (2017) suggest that smaller actors who share similar objectives could benefit from collaborating in some areas while continuing to compete in others. The authors argue that such 'co-opetition', i.e. forming professional networks, could increase legitimacy and visibility and thereby possibly attract new actors. Being part of a network comes at a cost, such as the investment of time and resources. Hence, valuable links to other actors are created and maintained within networks. Fusillo et al. (2020) find a tendency for firms to link with the 'friends of a friend', whereby actors that share a common collaboration partner form a link. Multiple-actor networks tend to behave in a cyclic manner, by which the termination of one project often leads to the initiation of another (Mosgaard and Kerndrup, 2016).

Table 4
Journals and the number of publications on green innovation networks.

Name of journal	Number of publications
Journal of Cleaner Production	23
Business Strategy and the Environment	6
European Journal of Innovation Management	3
Industrial Marketing Management	2
International Journal of Innovation and Sustainable Development	2
Supply Chain Management: An International Journal	2

4.2. Typical motivations for green innovation networks

In these networks, actors form both close and loose ties with other actors, which may change over time as innovation progresses. It is shown that network engagement is important when transforming knowledge into green innovation capability (Mellett et al., 2018). According to Mosgaard et al. (2014), network collaboration can be seen as a method for actors to overcome barriers to green innovation. It is shown that participation in green European research networks, i.e. networks that involve universities, positively affects green innovation (Fabrizi et al., 2018). Similarly, Dangelico (2016) argues that networking activities positively influence green innovation, in particular collaboration with diverse types of actors. Networks may help firms to overcome their shortcomings in green innovation by giving them access to new knowledge bases. For example, it is shown that firms with poor inventive capacity within green innovation are more likely to partner with more experienced firms (Fusillo et al., 2020). Rossignoli and Lionzo (2018) show that networks can enable the introduction of new concepts, knowledge and practices.

Suppliers are part of these networks and often share and develop new knowledge in joint innovation settings, including both product and service innovation (Kiefer et al., 2017). Customers can play multiple roles in green innovation networks, such as putting pressure on firms, which studies show has a positive impact on research and development investment and collaboration networks (Huang et al., 2016). In the early phases, customers may promote the development of additional features, provide knowledge and ideas and share end-user demands and environmental requirements (Melander, 2018; Pakura, 2020). By involving customers in these networks, firms are able to access future deliverables as well as anticipate their feasibility and potential economic success (Kiefer et al., 2017). In the end-phase, customers can act as pilot users to test a new innovation over a certain period of time (Pakura, 2020). Although it can be argued that suppliers and customers have similar roles in green innovation networks as in regular innovation networks, universities may have a different role. Fabrizi et al. (2018) argue that universities play a more prominent role in green innovation networks, which supports the idea that knowledge required for the implementation of green innovations is more complex and 'codified' than for regular innovations. Pakura (2020) shows that universities not only provide knowledge during the development of an innovation, but also during the commercialization phase by providing market knowledge and serving as platforms for the demonstration and testing of green innovations.

Networks need to be coordinated, which makes it important to bridge and share information between members (Fu et al., 2020). Kiefer et al. (2017) suggest that intermediaries can play a central role in green innovation networks by assisting firms. Hermann et al. (2016) show how intermediaries are important actors that facilitate collaboration by defining each actor's role, increasing network connectivity and scanning for information. However, Hermann et al. (2016) also suggest that intermediaries can be actors that participate in interactions both within the network and in institutional settings related to the innovations in development. Fliaster and Kolloch (2017) point out that there may be additional stakeholders involved, such as environmental activists, opinion leaders in local communities and other influential residents. These stakeholders can have a substantial impact on the implementation of green innovations. These different motivations and the common actors associated with them are listed in Table 5.

Fig. 2 provides a schematic map of the common motivations behind green innovation networks according to the level of organizational motivation for engaging in them and based on the phases of the innovation process. As depicted in the figure, and based on the arguments in the literature stated above, the motivation to engage in green innovation networks diminishes during the transition from idea/knowledge

Table 5
Different actor motivations in green innovation networks.

Motivation	Type of actors commonly associated with this motivation
Knowledge generation (idea, conception, design process, etc.)	Suppliers[b, h], customer[a, c, d, h], competitors and firms from other industries[h], research bodies[e, d, h], innovation platforms[f, h]
Knowledge sharing	Suppliers[b], research bodies[e], governments[e]
Demand generation	Customers[a], research bodies[e], governments[e, h]
Pilot and testing	Customers[c, d], research bodies[e, d], innovation platforms[h]
Implementation	Local governments[e], NGOs and activists[g], opinion leaders[g]
Commercialization	Research bodies[e, d]
Coordination and governance	Trade associations[g, h], government[e, g], intermediaries[b, f]
Institutionalization	Research bodies[e], NGOs[g], intermediaries[f]

[a] .Huang et al. (2016).
[b] Kiefer et al. (2017).
[c] Melander (2018).
[d] Pakura (2020).
[e] Fabrizi et al. (2018).
[f] Hermann et al. (2016).
[g] Fliaster and Kolloch (2017).
[h] Melander and Pazirandeh (2019).

generation towards development processes, with more costs/problems associated with, e.g., making technical changes. Halila and Rundquist (2011) show that networks are mainly important in the early phases of the innovation process (i.e. idea generation and concept definition), and then particularly with a focus of solving technological problems (illustrated by the left of the curve in Fig. 2). Similarly, Dangelico et al. (2013) point to the importance of the early phases of green innovation, arguing that the creation of networks is important for integrating green aspects into product design. This is not surprising and echoes discussions related to supplier engagement (Van Weele, 2014) and customer involvement (Öberg, 2010) in new product development projects.

While we did not find much evidence in the extant literature on green innovation networks during the development phases of the innovation process, as suggested in the literature, the motivation to engage in such networks increases again at the end of the innovation process, when the motivation is to commercialize and set industry standards. Motivations for joining green networks are diverse, knowledge exchange is an important reason, but networks can also serve other purposes, such as enabling standards-setting within an industry, piloting and commercialization (Kiefer et al., 2017) illustrated by the right of the curve in Fig. 2).

4.3. Common outcomes of green innovation network collaborations

The outcome of collaborating in networks for green innovation is that value is created at three levels: the individual firm (micro level), between actors (meso level) and in society (macro level) (Garcia et al., 2019). At micro level, the focus is on individual firms and organizations that struggle to maximize the benefits and minimize the costs of green innovation while also minimizing the impact on the environment. The meso level focuses on networks of actors, including supply chain actors, institutions, academic partners and governmental actors. Here, inter-organizational networks need to share knowledge. It is shown that firms with collaborative networks are more likely to develop green innovations (Zubeltzu-Jaka et al., 2018). Zhou et al. (2020) show that when network actors are more comfortable with embeddedness and knowledge-sharing practices, they take effective actions to develop green innovations. Here embeddedness refers to reciprocal relationships between actors whereby mutual investments result in collaborations and trust. Firms that have relationships with multiple actors and firms that are embedded in dense clusters perform better with respect to green innovations (Fusillo et al., 2020). At the macro level, the focus is on minimizing environmental impacts and maximizing social benefits.

Collaborating in networks for green innovation can have wide-ranging implications. Green innovations not only impact the environment, but as (Kiefer et al., 2017) suggest also have an impacts at the company level, such as changes in a business's offering, the structure of the firm, its supply chains and the type and degree of involvement and interaction it has with other actors. Another study found that a green innovation network influenced a group of actors' energy management, from focusing mainly on optimizing certain parts of their operations to considering energy management across their entire operations (Mosgaard and Kerndrup, 2016).

4.4. Common complexities and related obstacles in green innovation networks

There are a number of common complexities and related obstacles associated with green innovation networks. Fusillo et al. (2020) point out that the complexity of green innovation makes the technologies involved less exposed to standardization and knowledge codification. Within open green-innovation networks overall, firms were less willing to co-create, as value capture occurs at the macro level while the costs of innovation occur at the micro level. When cooperation did occur, it was more conservative because the cost of disruptive innovations would not necessarily translate into higher returns on investment for the contributing firm (Garcia et al., 2019).

Another complexity discussed by Garcia et al. (2019) relates to the different levels of the network: micro, macro and meso. The authors point out that value is created at the micro and meso levels of the

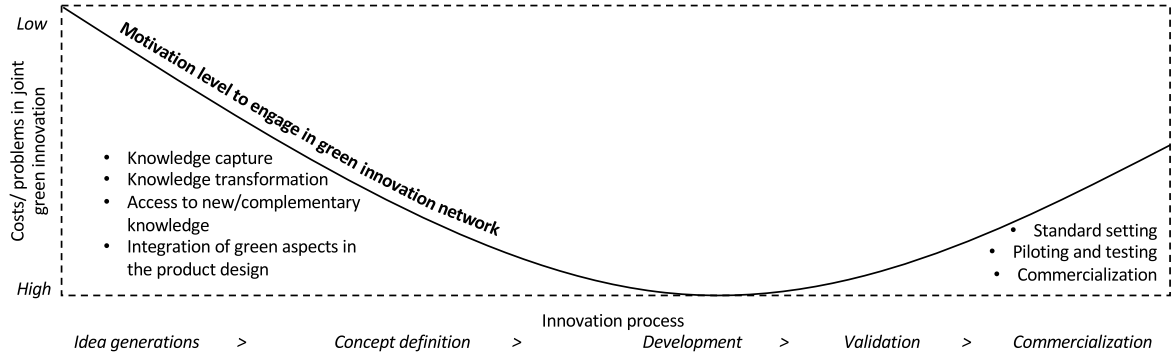

Fig. 2. Schematic view of the level of motivation to engage in green innovation networks and the common motivations based on the phases of the innovation process.

network. However, the goal of value capture is at the macro level, specifically environmental and social. Studies show that firms are less willing to commit resources and knowledge to green innovation, which could result in lower value capture for the network, society and the environment (Garcia et al., 2019). While facilitated networks can provide information on how micro-firms, defined here as firms with fewer than ten full-time employees, can become innovative, resource constraints and a lack of internal capabilities may prevent them from taking and implementing these ideas. In the same way, constraints on internal resources and capability may inhibit micro-firms from looking at further green innovation. The fulfilment of basic business needs is therefore required before micro-firms can network and consider green innovation (Mellett et al., 2018). See Table 6 for an overview.

Green innovation can be enabled through supply chain collaboration. However, this is a complex network activity that includes a large number of embedded actors with knowledge shared between them (Zhou et al., 2020). It has been shown that too many actors collaborating on a green innovation may make development more difficult (González-Moreno et al., 2019). By restricting the number of members and having closed networks, barriers are created that hinder wider engagement, potentially restricting access to new knowledge (Mellett et al., 2018). The authors show that up to five collaborating actors is beneficial for green innovation, but adding more actors to the network has a negative effect. It is suggested that to get the most out of collaborations with various actors, firms need to combine relational governance with traditional contractual governance (Hofman et al., 2020).

It is argued that knowledge exchange may require closer technological knowledge bases and continuous interactions, pointing to the benefits of close geographical proximity between actors (Fusillo et al., 2020). Similarly, it is argued that deep, frequent and intense relationships between actors are needed to foster knowledge sharing in green innovation networks (González-Moreno et al., 2019). While network engagement can facilitate access to external knowledge resources, effective network participation is partially dependent on actors' networking capabilities (Mellett et al., 2018). The ability to establish and manage collaboration, intense communication and knowledge flows with multiple external actors is important in green innovation (Dangelico, 2016). Zhou et al. (2020) point out that knowledge sharing, particularly of stakeholder knowledge, plays a key role in enabling green innovation. To foster fluent knowledge sharing between them, González-Moreno et al. (2019) suggest that actors develop deep, frequent and intense relationships. The authors argue that for actors to share enough valuable knowledge, there needs to be a level of trust between them, which is built through an understanding of their respective communication patterns and business cultures. Mylan et al. (2015) show that green innovation is more likely when network structures enable more collaborative relationships between actors. However, a technology-focused green innovation network is established through not only actors' knowledge of each other but also technical knowledge and previous experience (Mosgaard et al., 2014).

Some networks use platforms that enable actors to meet and share information. One example of such a platform is business incubation programmes that facilitate networking and offer various free services, providing both knowledge and support (Pakura, 2020). Cai and Zhou (2014) argue that firms with more efficient external networks tend to conduct more green innovation activities. It may be more difficult than expected for firms to collaborate with actors that are different from themselves. Potter and Graham (2019) argue that firms may struggle to manage complex networks of multiple actors during the process of developing green innovations. Studies point to diversity allowing actors to get the most out of their collaborations, making relationships and co-patenting more difficult (Potter and Graham, 2019). Garcia et al. (2019) argue that due to the competing goals of maximizing economic value and environmental benefits, firms engaged in green innovative networks end up accomplishing neither. It is shown that conflict between actors increases as an innovation approaches the production stage (Baraldi et al., 2011). When comparing non-green business networks with green business networks in different industries, Widjojo et al. (2020) find that in the non-green business networks, collaborations and dynamic interactions have a positive influence on marketing innovation. However, in green networks, actors focus on internal dynamic interactions to build internal value.

For sustainable transitions, the industry as a whole needs to recognize how new technologies can enable environmental sustainability. Horizontal collaborations face the dilemma of how to share sufficient knowledge to succeed in green innovation while simultaneously limiting knowledge spill to competitors (Melander and Pazirandeh, 2019). Other challenges within the network include power struggles, network evolution and mistrust between actors (Garcia et al., 2019). Power struggles may emerge from the competing goals of different actors. Agreements between actors take time, and actions are slow to be implemented. Mistrust of potential competitors may lead to withholding of knowledge, resulting in limits on innovation. In addition, fear of knowledge spill-over and future competition and doubts about partners' abilities to deliver what was promised had a negative effect on trust (Melander, 2018). Networks enable access to knowledge as well as other resources. However, to gain from a network, Pacheco et al. (2018) suggest that firms need to narrow the gap between the business and academic sectors, which have different goals, cultures, rhythms and languages. Getting market acceptance for an innovation can be difficult, hence it is important to link its green attributes to those such as style design, price and performance (Kiefer et al., 2017).

Table 6
Common sources of complexities and related obstacles in green innovation networks.

Source of complexity	Risen obstacle
The green innovation design process	Standardization of technologies
	Knowledge standardization/codification
	Lower economic outcome compared to environmental
Different levels of the network (i.e., micro, macro, meso)	Value generated and captured at different levels
	Lower value creation for the whole network
	Need for the industry to adopt the innovation
	Institutionalization
Multiple collaborating actors	Coordination
	Knowledge sharing versus spill-over
	Geographical proximity
	Frequency and intensity of interactions
	Goal incongruence
	Combining relational governance with contractual governance
	Actor power dynamics, trust and control
	Agreement and decision-making lead times

5. Discussion and research agenda

In this review we studied green innovation networks (including those related to products, services, processes, business models and marketing). We studied the type of actors and their roles and why they engage in networks. The networks included distant actors such as firms, suppliers and customers in other industries. Actors in networks engage in numerous activities and require coordination and trust to ensure the development of green innovations. There can be a wide range of environmental gains depending on the kind of green innovation, although many focus on reducing emissions, changing to more environmentally sustainable materials and technologies, and energy savings.

The complexities of the design process require a larger network of actors extending vertically, horizontally and across industries than in normal innovation networks. The greater number of actors involved, including from outside common partner networks of firms, presents a number of complexities related to knowledge sharing, risk and reward,

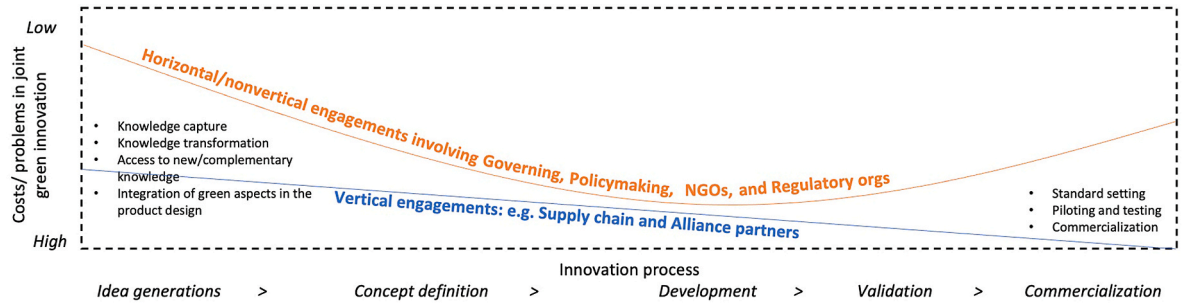

Fig. 3. Schematic view of the level of motivation for vertical (e.g. supply chain partners) and horizontal engagements (including, e.g., governments and regulators) in green innovation.

collaboration, coordination and governance. On the other hand, the relatively large number of actors in green innovation networks and the nature of issues of sustainability means that these networks extend in three levels: micro (e.g. firm and supply chain), meso (e.g. industry) and macro (e.g. society and institutions), creating a set of complexities and obstacles related to institutionalization and the sources and locations of value generation and value capture.

As illustrated in Fig. 3, according to the findings of previous studies (section 4.1) there is a difference in the level of engagement of policymakers, institutions of governance, NGOs and regulatory bodies in green innovation networks (e.g. Ceschin, 2013; Dangelico, 2016; Garcia et al., 2019; Melander and Pazirandeh, 2019) compared to non-green innovation networks (e.g. Waluszewski and Wagrell, 2013); the public sector appears more engaged and interested in taking an active role in the different stages of the innovation process. Compared to studies that suggest significant constraints on public sector involvement in innovation networks (e.g. Melander and Arvidsson, 2020; Waluszewski and Wagrell, 2013), this could suggest a different playing field for green innovation (further elaborated in research direction 1 below). In Fig. 2, the higher ends of the orange curve indicate greater levels of engagement by such actors in the early and later phases of the green innovation process. In this review we did not find limited support for engagement during the development phases.

Due to the higher levels of engagement by non-traditional supply chain/alliance actors (i.e. vertical) in green innovation compared to non-green innovation, we distinguish between those that are vertical (such as those between buyers and their suppliers) and those that are nonvertical (or horizontal). The engagement of non-traditional actors, such as those from the public sector or NGOs, in horizontal settings is one of the unique aspects of green innovation networks (elaborated on in research direction 2 below). The linear curve of vertical engagement is a schematic illustration of the traditional perspective towards joint innovations within supply chains, whereby engagement decreases as the cost of changes in development increases (i.e. in situations of high technological uncertainty where changing technology in the later stages of an innovation project becomes costly (Melander and Tell, 2014)). We did not find any difference in the green innovation context from this traditional view. However, it is still unclear which actors are present in the different stages of the green innovation process, what motivates them and how they interact; these are areas that need more empirical research in the future.

Based on the findings from this review, there are a number of research directions that would be interesting to investigate further.

5.1. The potential of horizontal collaborations in green innovation networks

Our review found a number of examples of collaborations between competitors (coopetition) and across industries through which firms shared knowledge in green innovation networks (see e.g. Melander and Pazirandeh, 2019; Mosgaard et al., 2014; Wicki and Hansen, 2017). Firms are able to distinguish between different markets and are thus able to collaborate in green innovation networks in one area while remaining competitors in another. Mosgaard et al. (2014) show that while actors in their study are competitors, they collaborated and shared knowledge in green innovation networks. The authors point out that this may have been because the green innovation was not seen as a commercial project. For small actors, collaborating with competitors in green innovation networks can increase legitimacy and visibility (Wicki and Hansen, 2017). Hence, actors could benefit from collaborating with competitors in green innovation networks while remaining competitors in other areas. Enabling collaboration between competitors could facilitate the goal of capturing value on the macro levels of the environment and society. Hence, this complexity, discussed by Garcia et al. (2019), which means that firms are less willing to commit resources and knowledge to green innovation networks, could be improved. More studies of actors' interactions in green innovation networks, including horizontal collaborations and coopetition, would shed more light on how firms can engage in green innovation networks.

5.2. The nature, nuances, hows and success factors of cross-sectoral partnerships in green innovation networks

Another type of collaboration often present in green innovation networks is cross-sectoral partnerships. In this respect there is significant scope for knowledge transfer between green innovation and cross-sectoral or public private partnerships (PPP) from the literature. Companies, public sector organizations and NGOs differ greatly in terms of purpose, resources, values and sources of power (Graf and Rothlauf, 2012), making successful cross-sectoral partnerships a challenge. PPP is a collaboration in which a public organization procures products and/or services from a private organization. It is common within, e.g., the infrastructure, health care and military sectors. The public sector (including national, regional and local government, as well as certain utilities) awards contracts to organizations through public procurement. Providing goods, services or construction work to public organizations involves a network of actors. Cross-sector partnerships with NGOs can range from philanthropic donations to integrated partnerships (Herlin, 2015; Seitanidi and Ryan, 2007). Partnerships between companies and NGOs have been found to produce social innovations as the sectors have complementary resources (Austin and Seitanidi, 2012). Due to the transactional nature of public procurement and regulations that hinder interaction between actors, innovation in these settings is rare (Uyarra et al., 2014; Waluszewski and Wagrell, 2013). However, a recent empirical study highlights three types of innovations in public procurement: product, service and business model, whereby interorganizational networks enable innovation despite their public procurement context (Melander and Arvidsson, 2020). In the literature reviewed in this paper, shown in Fig. 3, there were several mentions of cross-sectoral partnerships related to green innovation (e.g. see Table 5).

The second research direction relates to how green innovation can be enabled through interactions within PPP networks. In our review, the study by Hansen and Klewitz (2012) shows that firms can improve their work on green innovation by participating in PPP networks. Through these collaborations, firms learn to work more structurally or intensify their existing efforts within green innovation. Similarly, Klewitz et al. (2012) show that through PPP, a public intermediary is able to push smaller firms to make improvements in green innovation. The authors find that networks are important for facilitating green innovation, and both public and private actors facilitate green innovation by providing different types of support to firms. Networks within the PPP context are particularly important as they include multiple actors that engage in development. However, as discussed in the PPP literature, interactions between actors in PPP networks are limited, which acts as a barrier for innovation in these contexts (Uyarra et al., 2014; Waluszewski and Wagrell, 2013). As discussed by Håkansson and Axelsson (2020), interaction interfaces are not commonly used in PPP, since regulations have acted as a hindrance to these types of collaborations. However, there are exceptions, such as innovation partnerships, which open up opportunities for innovation within the PPP context (European Commission, 2017). This report also points out the importance of PPP for solving environmental problems through innovation. Hence, how PPP can be included in green innovation networks could be a fruitful future avenue of study. In the context of horizontal collaboration and PPP for green innovation, qualitative research, such as multiple case studies, would provide an in-depth insight into these types of collaborations; this would also enable the measurement of environmental gains from these green innovations.

5.3. *The possibilities and implications of considering users as actors in green innovation networks*

Another potential area for future research is the possibility of including users as actors in green innovation networks. Scholars have argued that users are important actors in networks and may take on multiple roles, such as lead users (Von Hippel, 1986) and users whose specific needs will become general needs in the future, and thus whom it may be beneficial to involve in innovation networks. Other roles include initiators, co-producers and inspirations for business development (Öberg, 2010). These actors take part in early and late phases of innovation, such as idea generation and prototype testing (Eslami and Lakemond, 2016; Gruner and Homburg, 2000). User involvement in these networks brings market information to innovation efforts, enabling access to market preferences and future market developments. However, there are drawbacks to involving users, as ground-breaking innovations may require new ways of viewing and solving existing problems. Studies show that while involving consumers is beneficial for incremental innovations, for radical innovations it is not (Menguc et al., 2014).

Although studies point to the importance of involving users in green innovation networks, arguing that firms are able to learn user preferences and expectations from them as well as engage them as pilot users for new innovations (Pakura, 2020), providing the opportunity to anticipate potential feasibility and economic success (Kiefer et al., 2017), getting market acceptance can be difficult. Environmental attributes are not sufficient, and firms need to provide innovations that are competitive with respect to, e.g., design, price and performance (Kiefer et al., 2017). Hence, an interesting area for future research would be user involvement in green innovation networks and how it is related to market acceptance. This area closely relates to marketing green innovations. As consumers and B2B customers become more aware of green offerings, branding, positioning and pricing, additional marketing issues will become the focus of more firms. For studies of market acceptance, a quantitative approach seems suitable as larger numbers of actors can be included in such studies.

6. Conclusions and limitations

While there is a large body of knowledge on interorganizational networks and green innovation, less is known of interorganizational networks aimed at green innovations, hence the need to systematize scientific literature on them. The review included a wide range of green innovations, including products, services, processes, business models and marketing. We identified the types of actors, their roles and why they engage in networks. This research discusses the kind of network relationships (e.g. new types or cross-sectoral) that need to be understood in studying these green innovations. Our review provides additional nuance to research on collaborative innovation in the context of green innovation networks. The review shows that firms share knowledge on green innovation vertically in their supply chains as well as across industries through horizontal collaborations. We identified dyadic, triadic, supply-chain and consortia collaborations. Based on the findings from the review, we identify and call for further research in a number of areas related to green innovation networks: horizontal collaboration, cross-sectoral collaboration including PPP and the potential of users as actors.

Our study has some limitations, the first being the selection of papers included in our review; we limited our search to the Scopus database, but there are of course a number of other databases available. Scopus was chosen as it is a comprehensive database that includes thousands of journals. Second, we chose only a few keywords, avoiding the use of multiple interchangeable terms; the justifications for these are described in the method section. The selection of keywords was the crucial part of the study as it affected the findings from the review and the future research agenda. The third limitation was our filtering, such as choosing to only include publications within business, management and accounting. As our interest was in the organizational aspects of network collaborations in green innovation, we decided that these areas of publication were most suitable. The choices made in our review process may have resulted in the exclusion of some relevant publications.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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