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Review

Open Innovation for the Construction Sector: Concept Overview and Test Bed Development to Boost Energy-Efficient Solutions

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Abstract: Open innovation has recently emerged as an important concept in both academic research and industrial practice, and it is now also becoming increasingly important in the public policy field due to the innovation challenges in different domains, such as climate change, sustainability, and growth to name a few, but only in some value chains (i.e., automotive, manufacturing, aerospace). According to a report by McKinsey and Co., the construction industry lags behind others in adopting innovations; in fact, less than 1% of the construction industry's revenue goes back into technology research and development. This work focuses on the current debate on the underdeveloped application of the open innovation (OI) approach to the construction sector. Namely, the foundational question is whether the OI model can be the answer to boosting innovation for the decarbonization of buildings. The research goal is to go a step further by analyzing its internal effectiveness, focusing on introducing and defining the Open Innovation Test Bed (OITB) concept. The study provides a systematic and bibliometric literature review of OI starting from a critical analysis of the concept definition and the evolution of the paradigm from the initial application to the first declination for the construction sector. All the steps analyzed allowed us to make an overall and comprehensive review of the OI concept, which is usually applied to other sectors, considering the ecosystem as the most effective declination of the OI paradigm for OITB development for building envelope solutions, thus providing answers to the two objectives identified in the introduction. Finally, the limitations of prior OI studies and the challenges for the OITB new construction paradigm are discussed, and we make recommendations for future opportunities and approach development to tackle and boost energy-efficient envelope solutions for the construction industries.

Keywords: open innovation; ecosystem; test bed; construction sector; energy-efficient envelope solutions

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1. Introduction

The snowballing involvedness of products and facilities, the fluctuating market demand, and the increased and different requests from different social groups are tendencies that push the introduction of new practices for companies to stay competitive. The externalization of data sources and their combination in the context of open innovation (OI) is one of the practices that can lead to increased success [1]. The OI concept was first introduced in 2003 by Henry W. Chesbrough, an American organizational theorist and professor at the University of California, Berkeley [2], as "a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market as the firms look to advance their technology" [3]. Chesbrough and his colleagues have made a major contribution to developing the theory, since they basically created an innovative novel concept that covers both "in-flows and outflows of knowledge" correlated to industrial research and development (R&D) and, consequently, allows us to

accelerate internal innovation, increase value and expand the markets [4]. Some of the external sources of knowledge that are most addressed are, for example, research institutes, universities, complementary companies, competitors, suppliers, and customers [5].

Since its coining, the "Open Innovation" concept has been considered as the smartest solution for the global drive toward innovation [6], thus contributing to the gradual paradigm shift that many sectors have recently been witnessing, from a traditional innovation model to a more open approach [7]. The OI concept has been also studied by means of a survey with the aim of identifying the industrial needs for open innovation in Europe for different-sized enterprises [1,8]. Companies, in fact, traditionally manage R&D actions internally and depend almost solely on their own efforts and services, which implies that only firms with appropriate internal resources can profit from their own innovations. However, Chesbrough argues that in current times and with such commercially valuable knowledge available, this closed innovation approach ("picking a man of genius, giving him money, and leaving him alone") is no longer sustainable [9].

In the literature, many research papers and studies underline that companies increase their benefits by using an OI approach to reach innovation with other small and medium-sized enterprises (SMEs) [5]. The "open" characteristic relates to the most recent cooperative paradigm, although this could be misleading as it could indicate "free" (World Intellectual Property Report. 2011). Indeed, firms must participate in proactive intellectual property (IP) management in line with the open innovation paradigm, rewarding feasible innovations internally while externally commercializing OI results [10].

In the context of collaborative relationships, in fact, firms must protect their innovations and know-how in a strategic way, to avoid the risk of losing their competitive advantage [11,12]. More precisely, as regards collaborations with external actors, Brant and Lohse suggest firms should use intellectual property rights (IPRs)—either registered (i.e., patents) or unregistered (i.e., trade secrets)—to better address the control and ownership of the outflows of knowledge, establishing proper knowledge management processes in advance to ensure that expertise is shared outside the company in a controlled and strategic way [13]. Moreover, IP could qualify as a new asset that can provide additional value and profit to the companies. According to Chesbrough, in fact, under the OI model companies should be both sellers and buyers of IP, pursuant to their own business model [14]. IP management and protection are only two of the reasons why many companies have felt the need to leave the traditional path and venture into a new and undeveloped method towards innovation. The key benefits of the OI paradigm shift basically consist of the following points:

(i) The firm does not bear the whole cost and hazard of the innovation and invention procedure, with the result that more companies now can achieve and realize their innovations, reducing the unused by-products of R&D and licensing to sell the new ones thanks to the increased traceability of IPRs;
(ii) Innovation is technically less burdensome and challenging for the company, thanks to the possibility of outsourcing some features of R&D and using outer business networks for its creations, also resulting in a shorter time to market;
(iii) Globalization ensures the full mobility of the skills, knowledge, and resources that firms under an open innovation model can now benefit from, ensuring long-term advantages such as improved absorptive capacity and organization learning for companies, at the same time increasing the excellence of their goods and facilities;
(iv) Regardless of the ever-increasing product complexity, companies can partner to strive more efficiently, starved of the difficulty and price of producing the whole products internally, thus generating more opportunities for firms located in less-thriving locations and for SMEs in general;
(v) Companies can more successfully compete in new markets and industry segments by combining skills and expertise from different entities across sectors. Thus, they can access specialized resources that they do not already have to stimulate the progress of innovative results.

Furthermore, the OI paradigm has been considered as a valuable concept that can play a big role on a larger scale in rapidly pushing the technological frontier outward, as well as actively stimulating technological advancement and innovation [15].

In recent developments, the concept of OI has become more complex by involving a high number of heterogeneous identities and different topics, such as international policies, being recognized, for example, as an essential part of one of the United Nations Sustainable Development Goals for 2030. This is true across multiple phases of the innovation process (i.e., integration, commercialization, etc.), thus creating a complete innovation ecosystem that can accelerate the transition toward sustainability. Moving from different value chains to a unique ecosystem means corporate sustainable development, energy efficiency and digitalization capability, which increase the firm's ability to survive in a very competitive market, creating Open Green Innovations that meet SDGs.

In that context, the objective of the present study is twofold: first, to provide an overview of how the research field of open innovation has developed from the coining of the term in 2003 [2] to date (Section 2), and identifying the sector in which this approach has been more easily applied due to the characteristics and needs of the respective value chain through a systematic literature review. The second goal of the manuscript is the theoretical positioning of the evolution to the latest OI 4.0 paradigm towards Open Green Innovation (OGI) to reply to the new market needs of sustainability and energy efficiency. Therefore, the research questions (RQs) that have guided the study are as follows:

RQ1. How can the OI concept be applied to the construction value chain, as has already been done successfully for other sectors?

RQ2. Does the Open Innovation Test Bed model boost Open Green Innovation and support the construction sector in remaining competitive, providing innovative building envelope solutions for the buildings' decarbonization target?

A dedicated focus on the construction sector, being the core of the presented study, is presented and discussed in Section 3, also considering that it has been pointed out as one of the most promising sectors for sustainable development [16]. Therefore, the theoretical gap that this research has discovered and furthermore investigated focuses on the analysis of which mechanism, from the already developed OI concepts, can affect and further boost an OGI application for the construction sector (Section 4). Moreover, the authors concentrate their study on the OI declination for building envelope solutions, having identified—from the results of the conducted systematic review—the "innovation ecosystem" paradigm, also called Open Innovation Test Bed (OITB), as the most suitable solution for the scope. Finally, a discussion of the results (Section 5), conclusions, and recommendations for future directions (Section 6) are presented.

The overall literature review on definitions and application of the most-common value chains of OI represents the theoretical evolution of the concept and the specific application to the construction sector with the declination to the OGI. The building envelope products are the new aspects analyzed and developed in this manuscript. The final goal is monitoring the first evidence of ongoing open innovation ecosystems experiences for the construction sector in the European context, in order to improve their application and feasibility by sharing lessons learned and even barriers encountered along their creation and development journey.

2. The Open Innovation Evolution: From Conceptualization to the 4.0 Version

The present section was conceived to provide a comprehensive review of the evolution of open innovation in the literature, thus implementing and integrating the outcomes of several previous studies that have been carried out on the subject. The objective is to map the OI literature in the nineteen-year period from 2003, when the open innovation concept was coined [3], to 2022, when the most recent articles were published, through a "bibliometric" approach (broadly used in identifying research trends), with the ultimate goal of assessing the potentiality of the OI paradigm in the construction sector.

The evaluation of the global scientific outputs has been based on Scopus, one of the leading worldwide databases for peer-reviewed scientific articles [17]. Only articles written in English and with "Open Innovation" as a keyword were included in this study, to avoid incorporating elements that may not have open innovation as their primary focus. The search has resulted in 7175 global scientific outputs, which were then analyzed according to the following ten criteria: (i) year, (ii) document type, (iii) source type, (iv) source, (v) subject area, (vi) keywords, (vii) country, and (viii) funding sponsor. The annual trend of scientific publications on OI in the Scopus database registered exponential growth in the period 2003–2011. Only eight years after the coining of the open innovation concept, in fact, the annual number of articles being published rapidly increased from 6 to 391. Since 2011, however, the trend has been quite stable, and it only saw a new promising rise from 2015 onwards, reaching an annual value of 743 in 2022. This was without considering 2023, as the study was not completed by 13 June 2023—the date of the last published study.

As outlined in the chart presented in Figure 1, the source types can be broken down as follows: (i) journals (which include articles, reviews and editorials, for a percentage of 60% of the total), (ii) conference proceedings (conference papers and reviews, 28% of the total), (iii) books (books and book chapters, 11% of the total), and (iv) other (e.g., notes, letters and surveys, for 1% of the total).

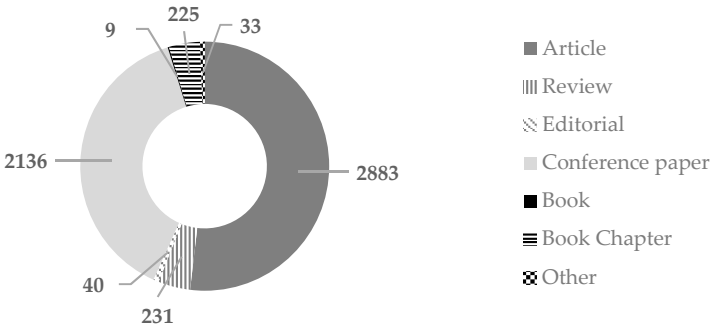

Figure 1. Breakdown of the number of global scientific outputs on open innovation per document type, according to the Scopus database.

All these documents refer to a total of 2212 different source titles, amongst which the ten most recurring are listed in Table 1. It is quite clear that open innovation has been addressed in a significant number of different journals, conferences and titles in general, with the result that the ones listed in the table below only cover 17.7% of the total publications that are the object of the present study.

Table 1. Breakdown of the number of global scientific outputs on OI per source title, focusing on the ten most recurring titles according to Scopus. Last updated on 11 July 2023.

Source Title	Number of Publications	Percentage of Total
Journal of Open Innovation: Technology, Market, and Complexity	393	5.5%
Sustainability (Switzerland)	166	2.3%
International Journal of Innovation Management	128	1.8%
Technological Forecasting and Social Change	107	1.5%
Lecture Notes in Computer Science	91	1.3%
R&D Management	86	1.2%
Research Policy	76	1.1%
Research Technology Management	72	1.0%
Technovation	72	1.0%
European Journal of Innovation Management	69	1.0%

The Scopus database has identified a total of 26 different subject areas regarding scientific publications on open innovation. Amongst those, Table 2 lists the five that have

been found as most frequent: (i) business, management and accounting, (ii) computer science, (iii) engineering, (iv) social sciences, and (v) economics, econometrics and finance.

Table 2. Breakdown of the number of global scientific outputs on OI per subject area, according to Scopus, five are the main areas. Last updated on 11 July 2023.

Subject Area	Number of Publications
Business, Management and Accounting	2453
Computer Science	1912
Engineering	1403
Social Sciences	1117
Decision Sciences	798

Figure 2 provides a graphical representation of the keyword frequency with reference to open innovation, giving greater prominence to those keywords that are more commonly used within global scientific outputs. For the sake of clarity, the graph considers only those keywords that have been used in at least 10 publications. The five most-used keywords, according to the Scopus database, are: (i) open innovation (used 4199 times), (ii) innovation (1894 times), (iii) collaboration (393 times), (iv) crowdsourcing (326 times), and (v) technological innovation (265 times). Followed by three emerging keywords that authors decided to consider as valuable indicators for future developments in relation to sustainability: (vi) sustainable development (240 times), (vii) digitalization (151 times), and (viii) test bed (105 times).

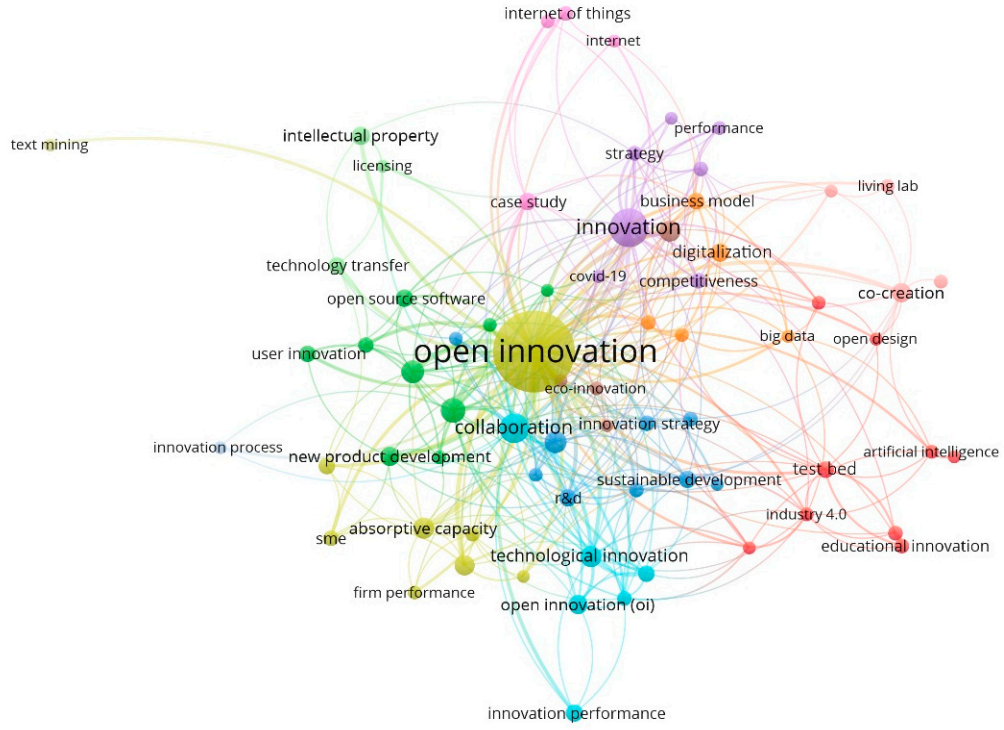

Figure 2. The most-common keywords used in articles published in the last two decades with reference to open innovation topics. Last updated on 11 July 2023.

The overall methodological steps taken to narrow down the number of articles from 8191 to the final sample of 105 are presented in Figure 3. They were deeply reviewed and are in line with the scope of the study, which is grounded on the two RQs.

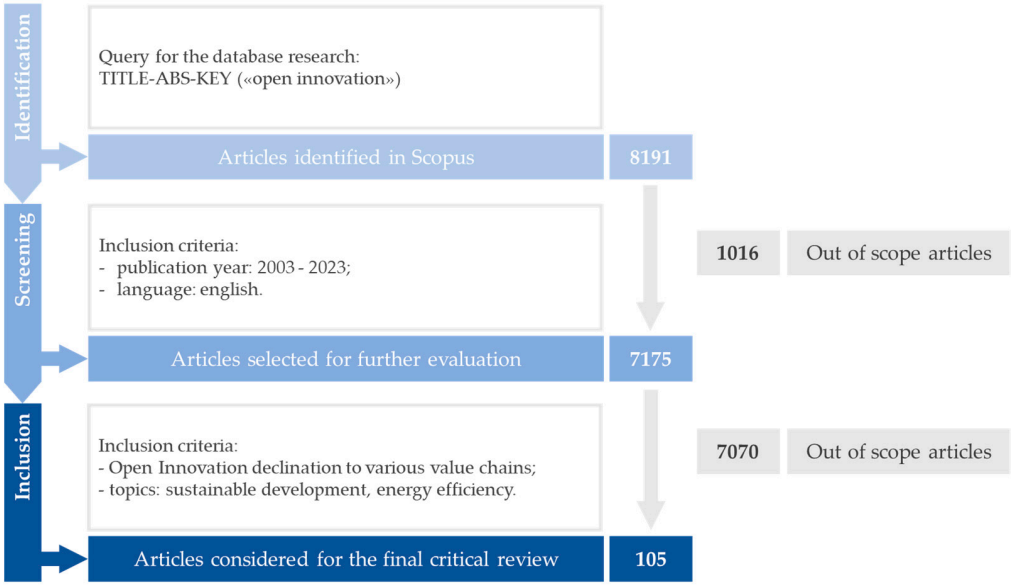

Figure 3. Flow chart of the methodological steps followed for the systematic review analysis according to inclusion/exclusion criteria.

The Scopus analysis realized referring to the period 2005–2023 shows that papers on open innovation have been published in 114 countries worldwide. As clearly represented in Figure 4, the first ten countries on OI publications are from: (i) the United States (939 publications), (ii) China (774), (iii) United Kingdom (713), (iv) Germany (696), (v) Italy (505), (vi) Spain (451), (vii) France (316), (viii) Netherlands (308), (ix) Finland (307), and (x) Sweden (303), underlining that most of them belong to the European Union (EU) context.

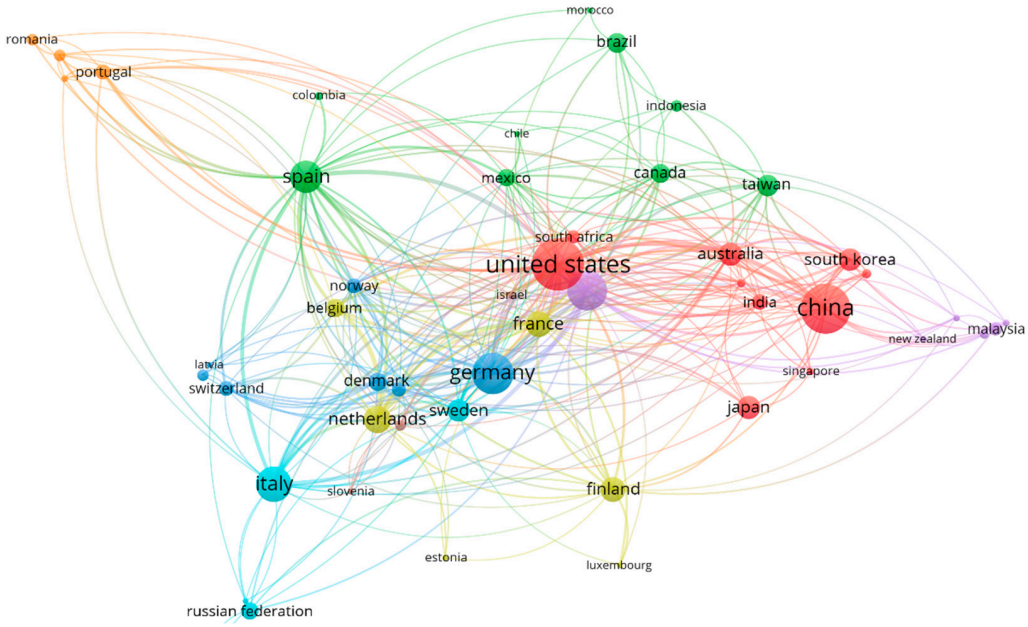

Figure 4. Worldwide distribution of the most active countries on open innovation. Last updated on 11 July 2023.

Therefore, this result is underlined by the fact that the European Commission (EC) has funded, under different research programmes, the majority of the OI publications (i.e., Seventh, H2020, Horizon Europe).

As addressed by Commissioner Moedas during his speech in June 2015, in fact, open innovation is the first pillar of the three strategic priorities that the European Commission

has set for European Union research and innovation policy: "Open Innovation, Open Science, and Openness to the World" [18]. Following this, in October 2017, the EU H2020 programme launched the Open Innovation Test Bed calls within the workplan on Nanotechnologies, Advanced Materials, Biotechnology and Advanced Manufacturing and Processing, thus enlarging and connecting the OI concept to the ecosystem term.

The first result obtained from the analysis of the OI literature review is the clear evidence that, according to the fields, perspectives, methods, and objectives considered, OI has declined and been investigated and applied differently, without a common thread. Hence, to summarize and clearly highlight the different declinations of the concept, Table 3 provides a chronological overview of the main definitions that have been found in the study period 2003–2022, linking each of them to the respective authors and objectives.

Regardless of the different definitions and declinations, the core idea behind the OI concept is the participation of several players (e.g., clients, providers, research centers, competitors, individuals, professionals and start-ups) in various flexible methods (e.g., collaborative agreements, crowdsourcing, co-creation, external business venturing, out-licensing, technology sales) that exceed the common paradigm of innovation cooperation and agreement research [19]. Methodological and systematic knowledge and capabilities that in the past were established in house are now derived from outward entities, which are selected and changed periodically [20,21]. Likewise, internal knowledge and technology are increasingly commercialized via external paths to markets [22,23]. Therefore, firms have moved to the upper end of the continuum between being closed and open, and, as a result, the locus of innovation has shifted.

OI theoretical developments can be classified into various methods, such as schools of thought [24], players, or procedures [22,25]. From the standpoint of firm processes, two types of data flow can be distinguished: outside-in (or inbound) and inside-out (or outbound). These two labels have allowed researchers to catalogue different OI actions, both formal and informal, that can be established by companies. It has been generally acknowledged [23] that inbound processes are usually favored, in particular by large companies [26], and different researchers have struggled to measure the impact of these processes on sustainable performance and digitalization capability [27–32].

The literature summarized in Table 3 reveals an increased correlation between openness and innovation, which facilitates and speeds up communication and technological developments like artificial intelligence (AI) and machine learning, as well as Big Data and other software interfaces, to manage cutting-edge robotics and blockchain solutions [33]. In particular, Dahlander et al. remarked in their retrospective work how those new tools have enabled companies to develop new business models, which rely on the company's ability to create, manage, share and store a massive amounts of data.

Table 3. Overview of the open innovation definition and concepts.

Author/s (Year)	Research Object	OI Definition
Chesbrough (2005) [3]	Open Innovation: the new imperative for creating and profiting from technology	*"A new approach has emerged, which assumes that firms "can and should use external ideas as well as internal ones, and internal and external paths to market" to make the most out of their technologies . . . valuable ideas can come from inside or outside the company and can go to market from inside or outside the company as well."*
Gassmann and Enkel (2004) [24]	Towards a theory of Open Innovation: three core process archetypes	*"Open innovation means that the company needs to open up its solid boundaries to let valuable knowledge flow in from the outside in order to create opportunities for cooperative innovation processes with partners, customers and/or suppliers. It also includes the exploitation of ideas and IP in order to bring them to market faster than competitors can."*

Table 3. *Cont.*

Author/s (Year)	Research Object	OI Definition
West and Gallagher (2006) [26]	Challenges of Open Innovation: the paradox of firm investment in open-source software	*"We define open innovation as systematically encouraging and exploring a wide range of internal and external sources for innovation opportunities, consciously integrating that exploration with firm capabilities and resources, and broadly exploiting those opportunities through multiple channels."*
Chesbrough, Vanhaverbeke and West (2006) [34]	Open Innovation: Researching a New Paradigm	*"Open innovation is the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation, respectively. [This paradigm] assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as they look to advance their technology."*
Laursen and Salter (2006) [35]	Open for innovation: the role of openness in explaining innovative performance among UK manufacturing firms	*"An open innovation model is using a wide range of external actors and sources to help them achieve and sustain innovation"*
Dittrich and Duysters (2007) [36]	Networking as a Means to Strategy Change: The Case of Open Innovation in Mobile Telephony	*"The system is referred to as open because the boundaries of the product development funnel are permeable. Some ideas from innovation projects are initiated by other parties before entering the internal funnel; other projects leave the funnel and are further developed by other parties."*
Hafkesbrink and Schroll (2011) [27]	Innovation 3.0: a new paradigm for multi-actor learning via embedding into knowledge communities	*"The notion of "embeddedness" is introduced to mark the increasing challenge of substantially integrating firms into their surrounding communities to assure the absorption of their exploitable knowledge. [. . .] In this context, Innovation 3.0 goes beyond OI ("Innovation 2.0") and clearly beyond Closed Innovation ("Innovation 1.0")."*
Lichtenthaler (2011) [11]	Open Innovation: past research, current debates, and future directions	*"Open innovation is defined as systematically performing knowledge exploration, retention, and exploitation inside and outside an organization's boundaries throughout the innovation process."*
Chesbrough and Bogers (2014) [37]	Explicating Open Innovation: Clarifying an Emerging Paradigm for Understanding Innovation	*"We define open innovation as a distributed innovation process based on purposively managed knowledge flows across organizational boundaries, using pecuniary and nonpecuniary mechanisms in line with the organization's business model."*
Lopez-Berzosa and Gawer (2014) [38]	Innovation Policy within Private Collectives: Evidence on 3GPP's Regulation Mechanisms to Facilitate Collective Innovation	*"In these increasingly common settings, the nature of the organizational challenge is to innovate together and preserve the collective welfare as defined by the overall vibrancy or performance of the ecosystem, while at the same time preserving or enhancing the individual performance of ecosystem members in competitive markets."*
Bogers et al. (2016) [39]	The Open Innovation research landscape: established perspectives and emerging themes across different levels of analysis	*"We propose a broad framework that combines the insights from earlier research with the prevailing relationships between the most important variables. Our integrative framework allows comparing, contrasting, and integrating the different perspectives at different levels of analysis, while offering a basis for further elaborating on and validating the categories within the framework as well as the boundaries in between."*
Lopes, Scavarda, Hofmeiter, et al. (2016) [40]	An analysis of the interplay between organizational sustainability, knowledge management, and Open Innovation	*"The manufacturer exists between suppliers and customers but, in terms of OI, collaboration with suppliers or customers can prove to be crucial for business. With the help of external knowledge, a firm can improve its sustainable innovation and positively influence organizational sustainability."*
Chesbrough and Vanhaverbeke (2018) [41]	Open Innovation and Public Policy in the EU with Implications for SMEs	*"Accordingly, the importance of OI and the acknowledgment that capable and intelligent minds exist outside of the firm has captured the attention of a large number of companies, venture capitalists, and governments around the globe who have subsequently provided additional funding opportunities."*

Table 3. *Cont.*

Author/s (Year)	Research Object	OI Definition
Alassaf, Dabić, Shifrer, et al. (2020) [8]	The impact of open-border organization culture and employees' knowledge, attitudes, and rewards with regards to Open Innovation: an empirical study	*"The expansion of available open innovation funding enabled companies to rethink the ways in which ideas are generated, fully embracing the era of OI."*
Costa, Matias (2020) [42]	Open Innovation 4.0 as an Enhancer of Sustainable Innovation Ecosystems	*"Developing open innovation strategies means combining knowledge, human and financial resources, and all players in the collaborative ecosystem. The promotion of sustainable innovation ecosystems is a co-creative process in which players must contribute and benefit from knowledge creation relying upon absorptive capacities and improvements".*
Roh, Lee, Ji Yang (2021) [29]	Open Green Innovation	*"Green innovation provides a valuable and irreplaceable resource for companies to develop their capabilities and lead to better business outcomes. [. . .] For companies, managers should regard open innovation activities as a window of opportunity to understand, absorb, and learn about complementary knowledge on green innovation from partners".*
Lee, Roh (2023) [31]	Open Innovation as strategy to mediate between digitalization capabilities and sustainable performance	*"Outbound open innovation is an antecedent factor that managers should consider before implementing open innovation [. . .] to leverage the key elements needed to pursue sustainability over time".*

The case of Amazon is presented in this context as a very compelling example of their theory, highlighting the potential of its virtual marketplace to profit from aggregated data provided directly by the technology platform users in the form of customer reviews. This can be seen as an "open innovation service" similar to the definition given by Chesbrough [43], in line also with the innovation ecosystem definition [44].

3. The Open Innovation Paradigm Evolution and Its Application to the Construction Sector

Referring to the extensive literature presented in Section 2, it emerges that a unique and widely agreed definition for innovation has not been defined to date. While traditionally the term "innovation" has been associated with something that companies engage in through internal R&D activities, currently many declinations, interactions, and tools are available to address and activate the innovation process.

In this section, the authors focus on how the OI paradigm can be used and applied to the construction sector to boost sustainability innovation, an urgent target from different points of view—as remarked both by recent studies presented in the literature review and the latest regulations and directives. In this context, OI only cannot be considered as a mere reverse method to traditional ones, crowdsourcing, or internal R&D management towards innovation. It is an entirely new context in which to determine innovative ideas; practice patents more efficiently; cooperate with academies, research centers, and startups; assess developing technologies; and develop alternative business models that a company can then put into the value chain. OI encourages something between entities that is beyond a knowledge-sharing economy. This collaborative method cannot be integrated into a dynamic ecosystem without a thorough understanding of the fundamental elements, processes, governance, and actors that comprise such an ecosystem. Any OI strategy requires financial foresight and an internal cultural shift, which Kamalapurkar presents as being structured in three main building blocks [45]. The first one is the leading priority and buy-in: leadership should aim at setting up a structural framework that inherently prioritizes innovation within its corporate operations. The second fundamental building block for any open-innovation-focused company is aligning the goals and operational capacities of

the business with the organization set-up. Choosing between de-centralized and centralized teams, lawyers, centers of excellence, and portfolios is key to successfully executing open innovation. The third building block is founded on the prevailing tools, processes, and culture. Socially open employees, vital resources allocated for the procurement of external knowledge, and the right tools and processes to successfully manage long-term collaborative and beneficial partnerships will influence and increase the adoption of OI.

The OI concept has primarily been studied within the context of Large-Scale Enterprises (LSE), whereby OI has been adopted as an explicit enterprise strategy [46]. Investigations on OI considering small and medium-sized enterprises (SMEs) are based on secondary and panel data [35]. A small number of studies have explored OI at the level of SMEs based on primary data [47,48]. Within the context of SMEs, Bianchi and colleagues stated that out-licensing is more interesting for SMEs as they possess a focused business portfolio with a very-high-level knowledge base and a need for support to adequately set up the financial and other aspects [22].

Van de Vrande and colleagues, contrastingly, declare that SMEs use OI in practice without a considerable change between manufacturing and service industries. However, medium-sized firms are, on average, more heavily involved in open innovation practices than small-sized firms [49].

The latest OI studies also highlight the application of the paradigm to new actors, areas, and domains such as small firms, no-profit organizations, public policy and low-tech industries, while early research on OI was limited only to on high-tech industries [50]. However, Chesbrough and Crowther stated that the method can also be applied to other value chains, remarking that the SMEs' growing target can be considered a dual aim: in terms of quantity of new products, but also in terms of revenue. These points of view are the key to boost the application of the OI method [51]. Chesbrough, in particular, suggests that the new horizon in terms of the development and implementation of the OI approach will concern the opening of the business models, which will provide numerous advantages to firms, such as an increased and more efficient way to create value by leveraging more ideas and capture greater value by utilizing their key assets, resources and positions [4]. As regards the building sector in particular, innovation could be defined as "the act of introducing and using new ideas, technologies, products and/or processes aimed at solving problems, viewing things differently, improving efficiency and effectiveness, or enhancing standards of living".

A quantitative survey conducted by Stichting Innovatie & Arbeid in 2014 [52] reveals that the construction sector is not a pioneer in OI, and the main barrier to that lies in the three main ways in which the cooperation could take place in the field: (i) between building materials and technology manufacturers, (ii) on site, and (iii) between manufacturers and those on site.

For this reason, protecting in-house knowledge seems to be the main barrier to cooperation between firms. Barrio and colleagues have proposed a model for technological innovation management in the construction sector, where the single firm develops their own in-house innovations to apply by themselves directly, creating a closed loop to address a kind of standardization of the management of innovation. The construction industry is based on projects and people, and for this reason, a breakdown with the traditional point of view has to be promoted highlights an innovative vision—this is a requirement for the creation of new technologies, ideas and inspiration [53].

In their critical review of construction innovation, Xue et al. [54] clearly stated that the conceptual framework of construction innovation can be summarized as four components: antecedents of construction innovation, innovation input, innovation process drivers, and innovation outcomes. According to their research results, one of the major issues of construction innovation is collaboration. In addition, the participants in construction innovation are a major factor in this area, involving the role of individuals, the behavior of adoption, and the innovation climate.

The increased number of studies on construction innovation remark that the domains investigated are multidisciplinary, and this also causes several difficulties in reaching the final goal, often also in relation to the firm size. Small firms, in fact, could encounter extra barriers compared to larger ones, as they are more geared to mass production and less interested in tailor-made solutions. This leads small firms to look for solutions with fellow SMEs, which is also easier and more convenient as a process thanks to a common business culture, less bureaucracy, and greater flexibility. Successful cooperation is based on trust, and that applies to all businesses. Instead of looking for cooperation, some firms generally opt to combine several activities in-house, since an interdisciplinary approach is required and cooperation is not always possible. This applies to cooperation both on-site and between manufacturers.

In that context, the change of the original concept from open innovation 1.0 to 2.0 [55] places more emphasis on the engagement of (i) industries, (ii) government, (iii) research center, academia, and in general also (iv) communities and users (the so-called "quadruple helix"), to answer to the social sphere in a sustainable and profitable way. OI 2.0 inverts the traditional models, in such a way that the innovation is now limited to the development of an "ecosystem" composed of various entities unified by a common purpose: to share, collaborate and innovate to co-create "shared value" [56]. Moreover, Porter and Kramer in 2011 remarked that the co-creation of shared value is feasible when firms move from optimizing short-term financial performance to optimizing both corporate performance and social conditions, thus increasing the value shared by both the corporation and the society in which it is embedded [57].

The most interesting feature of OI 2.0, according to Curley and Salmelin [58], is that instead of considering the user as a research object, the user experience becomes a new driver for innovation, and the user himself becomes an integral part of the innovation process and a co-creator of value. Cultivating and orchestrating innovation ecosystems is a fundamental component of OI 2.0; as Curley remarked in his work [59], innovation ecosystems can be created and transformed by creating a shared vision and reinforcing the vision with efficient and effective platforms for the emergence and then delivery of new innovations.

OI 2.0 has been clearly defined in the white paper for the EC—not as the panacea but as an essential component of the traditional innovation approaches in the construction chain to accelerate collective learning and value creation [60]. In this framework, governments and policymakers, in general, play a big role in the diffusion of the OI 2.0 paradigm as well and could support it and contribute in several different ways. One strategy, for example, could be to establish programs that foster the sharing of information and know-how between public research institutes and companies, in order to accelerate research and its application for the market [13]. Another viable method, to that end, could be to promote the development of open innovation "ecosystems" or Test Beds (OITBs) through public innovation grants, based on an effective IP management strategy developed in advance. OITB is the latest strategy in which the EU Commission has invested to foster a more holistic approach to research, development, and innovation (RD&I), thus triggering the birth of OI practice in different sectors, as is further detailed in Section 4.

OI 3.0 is considered, then, as the new paradigm for multi-actor learning via embeddedness in knowledge communities.

4. The Challenge of Open Innovation Test Beds (OITBs)

The development of innovative solutions is essential to meet Europe's long-term goals in relation to the three well-known aspects of sustainability (economy, social and environment) and the target of energy-consumption reduction and carbon neutrality.

The shift of innovation is moving towards a faster and demanding context, where industries encounter high barriers and limits to evaluating ideas and testing new products to be able to launch them into the market. This highlights the need to invest in new kinds of facilities where those activities can be deployed in a sustainable and affordable manner.

Europe decided to reply to this problem by implementing in its research programmes dedicated investments to support the creation of Open Innovation Test Beds (OITBs), which should become the reference and physical facilities for developing, testing, and upscaling innovations. Authors focus in this paper only on OITB for the construction sector, in particular for boosting the innovation of building envelope solutions, which is the core of the present work. However, the OITB has also been largely applied to the manufacturing, nanomaterials, and chemical industries.

The construction sector is, in fact, living in a challenging moment in reply to the ongoing initiative under the umbrella of the EU Green Deal. The New European Bauhaus (NEB) initiative, launched by the European Commission in 2020, promotes new ways of construction in which sustainability matches style, thus accelerating the green transition and supporting access to goods that are circular and less carbon intensive. Sustainability, aesthetic, and inclusion can summarize the key aspects that building projects and the construction materials and technologies must include in their development to remain competitive. Looking at the latest and most promising construction technologies, the dry envelope systems, thanks to their numerous advantages, such as versatility, reversibility, cost-effectiveness, reduced construction times, high-quality, safety, sustainability, and energy efficiency, can be considered a valuable solution to these compelling opportunities. The system, based on the mechanical assembly of several functional layers on a resistant framework made of steel, wood, or reinforced concrete, offers very high performances on several fronts, from energy savings to indoor well-being. Nevertheless, an elaborate and holistic approach seems to be required for implementing such new energy-efficient and user-centric solutions. Manufacturers might need the support of digital platforms and dedicated laboratories to raise awareness of innovation among potential customers, optimize market supply and demand, and comply with the regulatory framework and the processes of the certification of the product.

In this context, the OITB is a new model with high potential to reduce costs, investment risks, and the time to market in harmonized conditions, for materials characterization, modeling and upscaling to improve market access.

At the EU scale, the OITB can support all kinds of users independently from their geographical location, stimulating collaboration across Europe at the same time and contributing to the creation of a more open and connected innovation ecosystem.

The implementation of OITBs is expected to foster European networks of competencies along the entire value chain and match the needs of the industry by providing users with easy access to widely distributed facilities. Together, this accelerated innovation will create jobs, grow economies, and help deliver Europe's ambitions for a greener planet.

The European Health and Digital Executive Agency (HaDEA) in its explanatory notes and guidelines have defined the Open Innovation Test Beds (OITBs) as "entities, established in at least three Member States or Associated Countries, offering access to physical facilities, capabilities and services required for the development, testing, and upscaling of nanotechnology and advanced materials in industrial environments". Within that concept, the main objective foreseen for OITBs is to support the setting and operation of test beds, pilot lines, and demonstrators for the development, testing, and upscaling of innovative products and services in conjunction with industrial actors, innovators and start-ups. More practically, OITBs generally cover all tasks from the mock-up phase to the actual production, focusing in particular on the testing, monitoring, and validation of the materials and their characteristics, in compliance with the respective legal and regulatory constraints.

The development of such a set of entities is also fostered by the European Commission through the EU Horizon 2020 research and innovation funding programme, which supports not only the upscaling and engineering process but also a number of demonstration cases and dissemination activities, to showcase the most relevant capabilities and potentialities. Amongst the factors identified are: being open and accessible to any interested user from Europe and beyond, contributing to the creation of a more open and connected European

innovation ecosystem, and setting up networks of competences among OITBs along the entire value chain [61].

In the same context, another interesting and attractive form of OI ecosystem is the Living Labs (LLs) approach, which foresees the development and testing of innovative solutions and technology in general, in either a physical or virtual real-life experimentation environment, involving users as important informants and co-creators [62,63]. Living Labs can be overall defined, in fact, as co-creation ecosystems for human-centric research and innovation, where stakeholders form public–private–people partnerships (4Ps) of firms, public agencies, universities, institutes, and users, who all agree to cooperate for creating, prototyping, validating, and testing new technologies, services, products and systems in real-life contexts [64,65].

The Ongoing Open Innovation Ecosystems for the Construction Sector in the EU

Referring to the context outlined in the introduction of this section, the European Union has in place several projects, within the Horizon 2020 and Horizon Europe programmes, involving the implementation of open innovation ecosystems for the construction sector. These projects aim to identify on-demand, cost-effective, flexible, and material-based market solutions for energy- and resource-efficient buildings, in order to contribute to the large-scale diffusion of nearly zero-energy, zero-emission buildings.

The difficulty for these projects is to demonstrate that laboratory-based ideas can be replicated and scaled up to solutions that are appealing and profitable for real-world applications. It is critical to act on actual building envelopes through activities that have major economic, social, and environmental consequences, bringing together businesses, government, and citizens. These projects' Open Innovation Test Bed ecosystems, which provide services across many member states, help to enable these measures while also assisting developers of innovative construction solutions in adhering to EU regulatory norms, including adaptation to local specifications.

The ongoing EU open innovation projects are listed in chronological order, with details on funding program, duration, and consortium countries involved, in Table 4, while Table 5 provides an insightful overview of each project, highlighting keywords and main objectives taken from the projects' summary, which are available, respectively, in the Cordis database of the European Commission.

Table 4. List of the ongoing open innovation projects for the construction sector in the EU.

Project Title	Acronym	Program	Period	Consortium Countries
Building an Ecosystem for the up-scaling of lightweight multi-functional concrete and ceramic materials and structures [66].	LightCoce	Horizon 2020	2019–2023	BE; DE; EL; ES; IT; NL; PL; PT; SE
METAclustering for cross-sectoral and cross-border innovation ecosystem BUILDING for the European Construction, Additive Manufacturing and Nature-Based Solutions industrial sectors' SMEs [67].	METABUILDING	Horizon 2020	2020–2023	AT; BE; DE; ES; FR; HU; IT; PT; TR; UK
Functional and advanced insulating and energy harvesting/storage materials across climate-adaptive building envelopes [68].	Iclimabuilt	Horizon 2020	2021–2025	BE; CH; CY; DE; DK; EE; EL; ES; FR; IT; NO; PL; PT; SE; UK
Measuring Envelope products and systems contributing to the next generation of healthy nearly Zero Energy Buildings [69].	MEZeroE	Horizon 2020	2021–2026	AT; CH; DE; DK; ES; FR; IT; PL; SI; UK
An Open Innovation Ecosystem for exploitation of materials for building envelopes towards zero energy buildings [70].	Exploit4InnoMat	Horizon Europe	2023–2026	BE; CY; DE; EL; ES; IE; IT; LT; NO; RO; SE; TR

Table 5. List of the specific objectives for each of the open innovation projects for the construction sector in the EU.

	Keywords	Objectives
LightCoce	SMEs, lightweight multi-functional concrete and ceramic materials and structures	The objectives can be clustered into three groups related to the ecosystem: (i) setup, (ii) operation and sustainability, and (iii) validation. The LightCoce ecosystem supports the upscaling activities of EU SMEs and industries of lightweight multi-functional concrete and ceramic construction materials and structures.
METABUILDING	Metaclustering, SMEs, innovation networks ecosystem, digital platform	METABUILDING project has four main goals, listed as follows: provide support to SME innovation and strengthen the competitiveness of SMEs through international collaboration; support SMEs to overcome the COVID-19 crisis through innovation; cross-sectoral and cross-border collaborations to stimulate the innovation potential of the construction sector; and provide a digital platform to facilitate business and innovation in the construction sector.
Iclimabuilt	Materials development, cross-domain business ecosystem	There are 24 listed objectives of the project, which are clustered per 3 main phases of the ecosystem, like LightCoce. The key goals can be summarized as following: definition of nine Pilot Lines (PLs) for the ecosystem; validation of the OITB by a dedicated workflow on seven test cases, set up a (non-profit) joint venture to administer the ecosystem and provide links with financing schemes for SMEs to increase financial capabilities
MEZeroE	innovative construction products, envelope solutions, nearly zero-energy buildings; virtual marketplace	The objectives of the MEZeroE project can be categorized into two main groups: (i) related to OITB service validation, (ii) related to the long-term sustainability of the MEZeroE OITB. The final aim is to create a virtual marketplace ecosystem open to promoting cross-fertilization among stakeholders in the construction industry. The ecosystem offers modeling, testing, and monitoring services for nZEB (near-zero energy building), enabling envelope technology solutions (nEES), as well as specialized training.
Exploit4InnoMat	Material-based solutions, smart envelope systems, sustainable materials and products	The OITB Exploit4InnoMat network for building envelopes will focus on roofs and facades, with a range of materials such as: nano-enabled cement, non-cement premixes and ceramics, advanced coatings and glazing solutions loaded with aerogel, fibers, PCMs, and other nanomaterials. The final aim is to enable the replication of prototypes in different buildings while taking into consideration the trade-offs between the three sustainability pillars, the life cycle stages, and their impacts. Additionally, a tool combining BIM analysis, fast-track modeling, and simulation will enable a digital tool for utilizing building blocks to create a harmonized and aesthetically pleasing urban environment.

The concept behind most of those ecosystems is to enable SMEs and businesses to use a market-pull OI approach built on a strong connection with testbeds and services, with the final goal of driving innovative envelope solutions into the market as robust and low-risk products; develop cutting-edge envelope solutions through a digital platform that can match players and services that are not usually easily accessible in a single place; and sustain the rise of cross-sectoral, cross-border industrial value chains.

5. Discussion

The research results presented in this study can provide a substantial contribution to the ongoing stream of scientific literature on OI mechanisms. They firstly reply to RQ1 to identify which is the model most suitable for the application of OI to the construction sector, as has successfully already been done in other industries, by analyzing their ongoing initiatives and lessons learned.

The first results underlined that contributions are often still too fragmented and restricted to one dimension (i.e., user target or supplier innovation), and a new perspective

might be needed to integrate different aspects into a unique and more consistent open innovation declination.

The systematic literature reviews have presented essential theoretical and managerial implications and remarked that collaboration is one of the main concerns for the construction sector, for which the OI concept could be structured into four main components: (i) antecedents of construction innovation, (ii) innovation input, (iii) innovation process drivers, and (iv) innovation outcomes, to clearly identify the tendency of research on construction innovation and critical problems. Moreover, the evolution of OI is a very promising innovation model based on extensive networking and co-creative collaboration between all actors in society, spanning organizational boundaries well beyond normal licensing and collaboration schemes.

Chesbrough and Bogers [37] presented an overview of existing OI research into a multi-level framework, while Bogers et al. [39] suggested that the boundaries between different levels of analysis are becoming more permeable, but future research needs to adopt a cross-level approach in which this interaction is set out on a more complex course. An essential aspect of the research has been the identification of which technical domain companies are more prone to OI. It turned out that the most active figures in the development of both incremental and radical innovation are companies in the field of advanced technological solutions.

Regarding RQ2, the contribution of this study focuses on the knowledge body of the OITB paradigm, with a focus on its applicability to the construction sector as a young research field, also in relation to climate change, energy efficiency and decarbonization challenges. This leads to the need for integrating an Open Green Innovation perspective both in term of process and consumers.

Those topics have been further highlighted and investigated with the OITB development concept; therefore, they have become some of the main goals of the OITB initiatives presented in Section 4. The OITB approach allows us, in fact, to match the demands of SMEs/industries with the offers of research centers, testing facilities and Living Labs (LLs) and at the same time support secure knowledge transfer to disruptively change the building sector. This framework aims to provide structured knowledge to different stakeholders, with a pragmatic ambition of developing a trusted expertise network and self-sustaining beyond the project timeline, to span the so-called "valley of death" between research and product adoption. In this way, the projects aim to create a fertile ecosystem in the shape of a multi-side virtual marketplace, exploiting processes of cross-fertilization among stakeholders in the construction sector.

Comparing the five ongoing research projects, the main goal for all of them is the development of the respective Test Bed and its validation through pilot cases as proof of concept. In this review paper, the core sector is construction and the building envelope is the scope in particular, but the lessons learned from other sectors support and give insight into the definition of the OITB.

Another important common point is the importance of providing open access for SMEs or the industry to a single-entry point by existing or new pilot lines, to cover an overall process for the envelope products. This should be from the characterization and standardization modelling of the basic material to regulatory, safety and environmental assessment, using a scientific-based data and innovation management flow defined in accordance with the client. This activity can accelerate the development of additional leading-edge technology to boost the innovation transition and help small high-tech firms to scale up and cope with the continuous rising of technological complexity. The overall procedure is considered the fundamental step in each project to clarify the steps, actors, and tools necessary to reach the goal based on an open and common language, at the same time covering a wide range of expertise in a unique place and with a unique method.

Analyzing the projects in detail, it emerges that some focus mainly on the development of a digital platform open to all stakeholders of the enlarged built environment sector, which might help SMEs to find partners for collaborative projects, innovative technologies, and

information about available funding for SME innovation without specifying materials or products.

Some other projects, besides the platform, focus their OI support offer only on specific products or materials or requirements. For example, LightCoce focuses on lightweight multi-functional concrete and ceramic construction materials and structures, MEZeroE offers a series of OI services filtered by nine constructions segments (multifunctional envelope, multilayer façade systems; cladding systems; coatings and finishes; glazing and frames; membranes; joints and connectors; insulation; green roofs and green façades; active solar energy systems) through a virtual marketplace, while Exploit4InnoMat focuses mainly on nanomaterials for nZEB technologies.

All the projects are still under development and therefore only some general remarks can be made according to their preliminary results, which are disseminated by events or public reports.

The first highlight regards the geographical location of the funded open innovation ecosystem initiatives. The widespread EU distribution in most of the projects underlines how the different actors of the market, both universities with research centers and SMEs with companies of the construction industry, are ready for and highly interested in following the path toward innovation together in a close collaboration, to overcome IP barriers and enhance sharing knowledge management and facilities with a common aim: open innovation.

Another important aspect that boosts OITB application is the pragmatic and well-grounded mid- to long-term ambition of developing and consolidating a trusted expertise network between the actors of the value chain, to be active and self-sustaining well beyond the project timeline. This OI framework is in line with the EU Green Deal initiative and the carbon neutrality target, which require user-friendly and flexible instruments to reach their objectives. Therefore, the OITB paradigm facilitates the creation of network collaborations and boosts the introduction of new sustainable and energy-efficient solutions in the construction market.

6. Conclusions and Future Directions

To the best of the authors' knowledge, the present study represents one of the few attempts to conduct a comprehensive literature review that also focuses on practical applications of the OITB paradigm to the construction sector. We are confident about the usefulness of the first results for a wide variety of purposes, which hopefully are an inspiration for different actors (scholars, but also both public and private stakeholders) interested in the OI phenomenon within the building value chain.

The authors proposed a framework that can be used to distinguish differences between university–industry relationships and other corresponding collaborative organizational relationships.

Although the literature review has been conducted using a scientific and retraced method, the authors have to acknowledge possible limitations. It should be recorded, for example, that the bibliometric study presented in the manuscript relies only on the Scopus database, one of the leading sources for scientific publications, and therefore the results and findings might differ when using a different database. Also, the review only involves open innovation literature within the boundaries that have been defined in Section 2, thereby excluding articles that are still in the process of publication, without the keyword "Open Innovation", and were published in languages other than English. In future studies, other sources, databases, and languages may be explored.

In conclusion, the overall lessons learned are up to date and some important notes for further research have been summarized following.

The field of OI is still in evolution, and it offers a wide field in which academics, practitioners, and policymakers can be all actively involved. A significant theoretical contribution by the analyzed ongoing research projects is a confirmation of the usefulness of the applied measurement scales with the OITB paradigm, in particular in relation to the

emerging needs to stay competitive in a market that is pursuing a new destination and must respect and support the sustainable development goals.

The OITB can be considered a solution to the barriers that small, medium and large enterprises can encounter along the innovation path in relation to the testing and validating phase, which is usually the hardest step that sometimes requires dedicated regulations, standards or set-ups for tests unknown at the moment of the innovation. In this situation, usually, small firms with limited budgets or no dedicated R&D team will abandon the path, while only some large firms can, for example, develop their own dedicated test box where experimental analysis can be conducted [71]. Besides the limit dimension of the firm, even in this case, the box facility and the maintenance of such infrastructure and the scientific validation of the procedure will also require collaboration with universities or research centers, which can validate or verify the results obtained.

To overcome this situation and to increase access to these kinds of facilities for a larger number of SMEs, the development of different OITBs for the construction sector across Europe with dedicated pilot lines might serve as a basis for the further development of the paradigm and infrastructures for the design of future studies and needs, thus responding to the challenges of the market and supporting the decarbonization target.

This research should not be treated as exhaustive and closed, especially considering an issue as complex as the creation of effective mechanisms supporting the generation of OI in the construction sector. However, it aims to be a first insight into the knowledge of the OITB as a valuable model to boost green innovation both in terms of green processes and green producer/consumers, providing answers to the two RQs identified in the introduction.

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References

1. Rauter, R.; Globocnik, D.; Perl-Vorbach, E.; Baumgartner, R. Open Innovation and its effects on economic and sustainability innovation performance. *J. Innov. Knowl.* **2019**, *4*, 226–233. [CrossRef]
2. Chesbrough, H.W. The era of open innovation. *MIT Sloan Manag. Rev.* **2003**, *44*, 35–41.
3. Chesbrough, H.W. *Open Innovation: The New Imperative for Creating and Profiting from Technology*; Harvard Business Press: Cambridge, MA, USA, 2005.
4. Chesbrough, H.W. Why companies should have open business models. *MIT Sloan Manag. Rev.* **2007**, *48*, 22–28.
5. Von Hippel, E. Democratizing Innovation: The Evolving Phenomenon of User Innovation. *Int. J. Innov. Sci.* **2009**, *1*, 29–40. [CrossRef]
6. Bogers, M.; Chesbrough, H.W.; Heaton, S.; Teece, D. Strategic management of open innovation: A dynamic capabilities perspective. *Calif. Manag. Rev.* **2019**, *48*, 77–94. [CrossRef]
7. Cappa, F.; Rosso, F.; Hayes, D. Monetary and social rewards for crowdsourcing. *Sustainability* **2019**, *11*, 2834. [CrossRef]
8. Alassaf, D.; Dabic, M.; Shifrer, D.; Daim, T. The impact of open-border organization culture and employees' knowledge, attitudes, and rewards with regards to open innovation: An empirical study. *J. Knowl. Manag.* **2020**, *24*, 2273–2297. [CrossRef]
9. Chesbrough, H.W. The logic of open innovation: Managing intellectual property. *Calif. Manag. Rev.* **2003**, *45*, 33–58. [CrossRef]
10. Herzog, P.; Leker, J. *Open and Closed Innovation-Different Innovation Cultures for Different Strategies*; Gabler Verlag Wiesbaden: Wiesbaden, Germany, 2010.
11. Lichtenthaler, U. Open Innovation: Past Research, Current Debates, and Future Directions. *Acad. Manag. Perspect.* **2011**, *25*, 75–93.
12. Pénin, J.; Hussler, C.; Burger-Helmchen, T. New shapes and new stakes: A portrait of open innovation as a promising phenomenon. *J. Innov. Econ.* **2011**, *7*, 11–29. [CrossRef]
13. Brant, J.; Lohse, S. *Innovation and Intellectual Property Series: The Open Innovation Model*; International Chamber of Commerce (ICC): Paris, France, 2014. Available online: https://iccwbo.org/content/uploads/sites/3/2014/10/THE-OPEN-INNOVATION-MODEL-1.pdf (accessed on 25 May 2023).
14. Chesbrough, H.W. Open Innovation: Striving for Innovation Success in the 21st Century. In *Reinventing the Company in the Digital Age*; BBVA: Bilbao, Spain, 2015.
15. Huizingh, E.K.R.E. Open innovation: State of the art and future perspectives. *Technovation* **2011**, *31*, 2–9. [CrossRef]
16. Hossain, M.; Islam, K.; Sayeed, M.A.; Kauranen, I. A comprehensive review of open innovation literature. *J. Sci. Technol. Policy Manag.* **2016**, *7*, 2–25. [CrossRef]

17. Scopus. Available online: https://www.scopus.com/ (accessed on 28 May 2023).
18. Moedas, C. (Commissioner for Research, Science and Innovation). Personal communication. In Proceedings of the 'A New Start for Europe: Opening up to an ERA of Innovation' Conference, Brussels, Belgium, 22 June 2015. Available online: https://ec.europa.eu/commission/presscorner/detail/en/SPEECH_15_5243 (accessed on 27 May 2023).
19. Keupp, M.M.; Gassmann, O. The Past and the Future of International Entrepreneurship: A Review and Suggestions for Developing the Field. *J. Manag.* **2009**, *35*, 600–633. [CrossRef]
20. Almirall, E.; Casadesus-Masanell, R. Open versus Closed Innovation: A Model of Discovery and Divergence. *Acad. Manag. Rev.* **2010**, *35*, 27–47.
21. Chiaroni, D.; Chiesa, V.; Frattini, F. The Open Innovation Journey: How Firms Dynamically Implement the Emerging Innovation Management Paradigm. *Technovation* **2011**, *31*, 34–43. [CrossRef]
22. Bianchi, M.; Campodall'Orto, S.; Frattini, F.; Vercesi, P. Enabling open innovation in small- and medium-sized enterprises: How to find alternative applications for your technologies. *RD Manag.* **2010**, *40*, 414–431. [CrossRef]
23. Gassmann, O. *Opening up the Innovation Process: Towards an Agenda*; University of St. Gallen: St. Gallen, Switzerland, 2006; Volume 36.
24. Gassmann, O.; Enkel, E. *Towards a Theory of Open Innovation: Three Core Process Archetypes*; University of St. Gallen: St. Gallen, Switzerland, 2004; Volume 6.
25. Enkel, E.; Gassmann, O.; Chesbrough, H.W. Open R&D and Open Innovation: Exploring the Phenomenon. *RD Manag.* **2009**, *39*, 311–316.
26. West, J.; Gallagher, S. Challenges of Open Innovation: The paradox of firm investment in open-source software. *RD Manag.* **2006**, *36*, 319–331. [CrossRef]
27. Hafkesbrink, J.; Schroll, M. Innovation 3.0: Embedding into community knowledge-Collaborative organizational learning beyond Open Innovation. *J. Innov. Econ. Manag.* **2011**, *1*, 55–92. [CrossRef]
28. Yang, J.Y.; Roh, T. Open for Green Innovation: From the Perspective of Green Process and Green Consumer Innovation. *Sustainability* **2019**, *11*, 3234. [CrossRef]
29. Roh, T.; Lee, K.; Ji Yang, J.Y. How do intellectual property rights and government support drive a firm's green innovation? The mediating role of open innovation. *J. Clean. Prod.* **2021**, *317*, 128422. [CrossRef]
30. Lee, M.-J.; Roh, T. Unpacking the sustainable performance in the business ecosystem: Coopetition strategy, open innovation, and digitalization capability. *J. Clean. Prod.* **2021**, *317*, 128422. [CrossRef]
31. Lee, M.-J.; Roh, T. Digitalization capability and sustainable performance in emerging markets: Mediating roles of in/out-bound open innovation and coopetition strategy. *Manag. Decis.* **2023**. [CrossRef]
32. Bigliardia, B.; Dolci, V.; Filippelli, S.; Petronia, A.; Pinia, B.; Tagliente, L. The adoption of Open Innovation in Manufacturing: A review. *Procedia Comput. Sci.* **2023**, *217*, 1765–1774. [CrossRef]
33. Dahlander, L.; Gann, D.M.; Wallin, M.W. How open is innovation? A retrospective and ideas forward. *Res. Policy* **2021**, *50*, 104218. [CrossRef]
34. Chesbrough, H.W.; Vanhaverbeke, W.; West, J. *Open Innovation: Researching a New Paradigm*; Oxford University Press: Oxford, UK, 2006.
35. Laursen, K.; Salter, A. Open for innovation: The role of openness in explaining innovation performance among UK manufacturing firms. *Strateg. Manag. J.* **2006**, *27*, 131–150. [CrossRef]
36. Dittrich, K.; Duysters, G. Networking as a Means to Strategy Change: The Case of Open Innovation in Mobile Telephony. *J. Prod. Innov. Manag.* **2007**, *24*, 510–521. [CrossRef]
37. Chesbrough, H.W.; Bogers, M. Explicating Open Innovation: Clarifying an emerging paradigm for understanding innovation. In *New Frontiers in Open Innovation*; Oxford University Press: Oxford, UK, 2014; pp. 3–28.
38. Lopez-Berzosa, D.; Gawer, A. Innovation policy within private collectives: Evidence on 3GPP's regulation mechanisms to facilitate collective innovation. *Technovation* **2014**, *34*, 734–745. [CrossRef]
39. Bogers, M.; Zobel, A.K.; Afuah, A.; Almirall, E.; Brunswicker, S.; Dahlander, L.; Frederiksen, L.; Gawer, A.; Gruber, M.; Haefliger, S.; et al. The Open Innovation research landscape: Established perspectives and emerging themes across different levels of analysis. *Ind. Innov.* **2016**, *24*, 8–40. [CrossRef]
40. Lopes, C.; Scavarda, A.; Hofmeister, L.; Thomé, A.M.T.; Vaccaro, G.L.R. An analysis of the interplay between organizational sustainability, knowledge management, and open innovation. *J. Clean. Prod.* **2016**, *142*, 476–488. [CrossRef]
41. Chesbrough, H.W.; Vanhaverbeke, W. Open Innovation and Public Policy in the EU with Implications for SMEs. In *Researching Open Innovation in SMEs*; World Scientific Book Chapters; World Scientific: Singapore, 2018.
42. Costa, J.; Matias, J.C.O. Open Innovation 4.0 as an Enhancer of Sustainable Innovation Ecosystems. *Sustainability* **2020**, *12*, 8112. [CrossRef]
43. Felin, T.; Zenger, T.R. Closed or Open Innovation? Problem solving and the governance choice. *Res. Policy* **2014**, *43*, 914–925. [CrossRef]
44. Pushpananthan, G.; Elmquist, M. Joining forces to create value: The emergence of an innovation ecosystem. *Technovation* **2022**, *115*, 102453. [CrossRef]
45. Kamalapurkar, A. *Building Blocks of Open Innovation*; Capgemini Report; Capgemini: Hong Kong, China, 2019.
46. Barret, G.; Dooley, L.; Bogue, J. Open innovation within high-tech SMEs: A study of the entrepreneurial founder's influence on open innovation practices. *Technovation* **2021**, *103*, 102232. [CrossRef]

47. Kim, H.; Park, Y. The effects of open innovation activity on performance of SMEs: The case of Korea. *Int. J. Technol. Manag.* **2010**, *52*, 236–256. [CrossRef]
48. Parida, V.; Westerberg, M.; Frishammar, J. Inbound open innovation activities in high-tech SMEs: The impact on innovation performance. *J. Small Bus. Manag.* **2012**, *50*, 283–309. [CrossRef]
49. Van de Vrande, V.; De Jong, J.P.; Vanhaverbeke, W.; De Rochemont, M. Open innovation in SMEs: Trends, motives and management challenges. *Technovation* **2009**, *29*, 423–437. [CrossRef]
50. Bogers, M.; Chesbrough, H.W.; Moedas, C. Open Innovation: Research, Practices, and Policies. *Calif. Manag. Rev.* **2018**, *60*, 5–16. [CrossRef]
51. Chesbrough, H.W.; Crowther, A.K. Beyond high tech: Early adopters of open innovation in other industries. *RD Manag.* **2006**, *36*, 229–236. [CrossRef]
52. Foundation Innovation & Work. Available online: www.serv.be/sites/default/files/documenten/Summary_IOA_2014.pdf (accessed on 24 May 2023).
53. Yepes, V.; Lòpez, S. Knowledge management in the construction industry: Current state of knowledge and future research. *J. Civ. Eng. Manag.* **2021**, *27*, 71–680. [CrossRef]
54. Xue, X.; Zhang, R.; Yang, R.; Dai, J. Innovation in construction: A critical review and future research. *Int. J. Innov. Sci.* **2014**, *6*, 111–126. [CrossRef]
55. Bugshan, H. Open innovation using Web 2.0 technologies. *J. Enterp. Inf. Manag.* **2015**, *28*, 595–607. [CrossRef]
56. Fox, C.; Albertson, K. *Innovation and the Evidence Base*; Academic Insights 2020/08; HM Inspectorate of Probation: Manchester, UK, 2020.
57. Porter, M.E.; Kramer, M.R. The Big Idea: Creating Shared Value. How to Reinvent Capitalism–and Unleash a Wave of Innovation and Growth. *Harv. Bus. Rev.* **2011**, *89*, 62–77.
58. Curley, M.; Salmelin, B. Open Innovation 2.0 New Paradigm; White Paper for EU Commission. Available online: https://ec.europa.eu/futurium/en/system/files/ged/24-oispgopeninnovation20anewparadigm-whitepaper.pdf (accessed on 22 May 2023).
59. Curley, M. The Evolution of Open Innovation. *J. Innov. Manag.* **2015**, *3*, 9. [CrossRef]
60. Rayna, T.; Striukova, L. Open innovation 2.0: Is co-creation the ultimate challenge? *Int. J. Technol. Manag.* **2015**, *69*, 38–53. [CrossRef]
61. European Commission. Open Innovation Test Beds Guidelines for Internal Management and Access Conditions, May 2018. Available online: https://ec.europa.eu/research/participants/data/ref/h2020/other/guides_for_applicants/h2020-im-ac-innotestbeds-18-20_en.pdf (accessed on 20 May 2023).
62. Westerlund, M.; Leminen, S. Managing the challenges of becoming an Open Innovation company: Experiences from Living Labs. *Technol. Innov. Manag. Rev.* **2011**, *1*, 19–25. [CrossRef]
63. Ballon, P.; Schuurman, D. Living Labs: Concepts, tools and cases. *Info* **2015**, *17*. [CrossRef]
64. Schaffers, H.; Cordoba, M.; Hongisto, P.; Kallai, T.; Merz, C.; van Rensburg, J. Exploring Business Models for Open Innovation in Rural Living Labs. In Proceedings of the 13th Conference on Concurrent Enterprising, Sophia-Antipolis, France, 4–6 June 2007.
65. Perkmann, M.; Walsh, K. University Industry Relationships and Open Innovation: Towards a Research Agenda. *Int. J. Manag. Rev.* **2007**, *9*, 259–280. [CrossRef]
66. LightCoce H2020 Project. Available online: https://cordis.europa.eu/project/id/814632 (accessed on 23 May 2023).
67. METABUILDING H2020 Project. Available online: https://cordis.europa.eu/project/id/873964 (accessed on 28 May 2023).
68. Iclimabuilt H2020 Project. Available online: https://cordis.europa.eu/project/id/952886 (accessed on 28 May 2023).
69. MEZeroE H2020 Project. Available online: https://cordis.europa.eu/project/id/953157 (accessed on 23 May 2023).
70. Exploit4InnoMat Horizon Europe Project. Available online: https://cordis.europa.eu/project/id/101092339 (accessed on 28 May 2023).
71. Salvalai, G.; Sesana, M.M. Experimental analysis of different insulated façade technologies in summer condition. *J. Green Build.* **2019**, *14*, 77–91. [CrossRef]