Journal of Cleaner Production 377 (2022) 134325

Contents lists available at ScienceDirect

Journal of Cleaner Production

journal homepage: www.elsevier.com/locate/jclepro

Intellectual property strategies for green innovations - An analysis of the European Inventor Awards

Pratheeba Vimalnath [a,*], Frank Tietze [a], Akriti Jain [b], Anjula Gurtoo [c], Elisabeth Eppinger [d], Maximilian Elsen [a]

[a] Department of Engineering, Innovation and Intellectual Property Management Laboratory, Centre for Technology Management, Institute for Manufacturing, University of Cambridge, Cambridge, CB3 0FS, UK
[b] International Management Institute - New Delhi, B-10, Qutab Institutional Area, Tara Crescent, New Delhi, Delhi 110016, India
[c] Centre for Society and Policy, Indian Institute of Science, Bengaluru 560012, Karnataka, India
[d] University of Applied Sciences for Technology and Economics (HTW) Berlin, Wilhelminenhofstraße 75A, 12459, Berlin, Germany

ARTICLE INFO

Keywords:
Intellectual property
Patent licensing
Green innovation
Sustainability
European inventor award
New ventures

ABSTRACT

To drive sustainability on a global scale for a carbon-neutral future, green innovations and a better understanding of how intellectual property (IP) impacts their research, development, and diffusion are needed. In this paper, we identify IP models adopted by green innovators in three innovation process phases, namely: research; development/commercialization; and diffusion phases, contrasting findings across three organization categories: new ventures; universities; and established firms. Our analysis is based on a qualitative content analysis of 57 green innovations recognized by the European Inventor Award, a highly prestigious international prize awarded annually by the European Patent Office. The analysis shows the degree of openness in IP sharing increasing along the innovation process. Unlike established firms who adopt closed IP models predominantly throughout the innovation process phases, new ventures and universities adopt closed IP models in research and development phases to protect inventions and later share the IP, primarily patents, with others via licensing (exclusive or non-exclusive) to accelerate commercialization and diffusion for broader sustainability impact. The findings point towards a need for interventions at managerial and IP policy level that move beyond incentivizing innovations through exclusivity towards facilitating strategic and collaborative approaches to IP sharing that can accelerate sustainability transitions.

1. Introduction

Sustainability-oriented green innovations actively drive sustainability impacts on a global scale for a carbon-neutral future (Schiederig et al., 2012). Accordingly, research, development, commercialization, and wide diffusion of green innovations, such as alternative energy resources and climate change mitigation technologies, become vital to combat climate change and foster a sustainable future (Abbott, 2018; Henry and Stiglitz, 2010; Leach et al., 2012). New ventures are often considered vital for driving clean and green innovations (Henry et al., 2020), while universities are a key driver for green technology research (Eppinger et al., 2021; Purcell et al., 2019). However, green or environmental innovation processes are more complex and challenging than non-environmental innovation processes (Jakobsen and Clausen, 2016). Despite the close and critical relationship between innovation and intellectual property (IP), the role of IP for sustainability impact remains inadequately understood. IP models that facilitate green innovations are not adequately recognized in the literature (Eppinger et al., 2021). Such lack of evidence-based insights hinders structured IP-related managerial and policy discussions for sustainability.

In this paper, we explore the role of IP for sustainability through the following research questions: 1) Which IP models are adopted by green innovators along the three phases of the green innovation process, namely research, development/commercialization, and diffusion to create positive environmental impact? 2) Do IP models adopted for creating positive environmental sustainability impact differ among new

Abbreviations: IP, Intellectual Property.

* Corresponding author.
E-mail addresses: pv302@cam.ac.uk (P. Vimalnath), frank.tietze@eng.cam.ac.uk (F. Tietze), akriti.jain@imi.edu (A. Jain), anjula@iisc.ac.in (A. Gurtoo), Elisabeth.Eppinger@HTW-Berlin.de (E. Eppinger), mhce2@cam.ac.uk (M. Elsen).

https://doi.org/10.1016/j.jclepro.2022.134325
Received 4 October 2021; Received in revised form 29 August 2022; Accepted 20 September 2022
Available online 25 September 2022

ventures, universities, and established firms?

Green innovation refers to novel products, processes, and technologies aimed at reducing environmental or ecological costs or risks (Ali et al., 2021). In this paper, we adopt the OECD definition of green or eco-innovation: "implementation of new, or significantly improved products (goods and services), processes, marketing methods, organisational structures, and institutional arrangements which – with or without intent – lead to environmental improvements compared to relevant alternatives" (OECD, 2009, p. 40). Based on Vimalnath et al. (2020), we adopt the definition of "IP model" as the way an actor controls the ownership, access, and usage rights for a combination of relevant complementary IP assets (both formal IP rights such as patents and trademarks, and informal IP assets such as know-how and data) to achieve a specific purpose within a specific setting. "IP strategy" is then defined as the decision-making guidance of an actor regarding the selection and combination of different "IP models" to maximize value creation and capture in support of, and alignment with, the organizational objectives (Vimalnath et al., 2020).

Intellectual property rights (IPR), a well-established policy instrument for promoting innovations, is increasingly becoming a strategic tool. Firms make strategic use of formal IPR such as patents, and informal IP such as process know-how, for managing green technologies and collaborative innovation processes (Holgersson et al., 2018; Kalanje, 2006). The strategic decisions on how to use the IP can fall within the two extremes of an IP usage scale, namely i) sharing inventions and IPR through royalty-free licensing; or ii) restrict access through IP protection and non-sharing (Chesbrough et al., 2014; Vimalnath et al., 2020). Between these two extremes, the "hybrid" IP models include, for example, selective licensing, patent pools, and pledges (Contreras, 2015; Sternkopf et al., 2016). According to Vimalnath et al. (2020), IP models can be broadly classified as closed, semi-open, or fully open IP models. Which of these IP models facilitate the research, development, commercialization and diffusion of green innovation remains less understood. Possibly, all these IP models become relevant but under different settings, possibly in different phases of the green innovation process.

The literature presents mixed evidence, with inconsistencies about the role of these different IP models in facilitating green innovations. Some studies argue for IP protection as essential for incentivizing innovation and facilitating green and socially beneficial technology transfer (Alonso-Martínez, 2018; Ferreira et al., 2020; Jain and Gurtoo, 2021; Jardon and Dasilva, 2017; Matricano, 2020). In contrast, others show IP protection as detrimental to green innovators (Correa, 2004; Libaers et al., 2016; Söderholm, 2020). From the macro-level economics and policy perspectives, differences in IP regimes, economic conditions, and absorptive capacities contribute to variations in research, development and diffusion of green innovations (Aboelmaged and Hashem, 2019; Huang et al., 2017; Qi et al., 2021; Swanson and Goeschl, 2014). At the innovation level, two other aspects that could potentially drive green innovation from the IP perspective are actor specificities, i.e., who (new venture, university or established firm) owns and uses the IP (Mann, 2004; Shane and Cable, 2002), and the IP dynamics across innovation phases (Bican et al., 2017; Stefan and Bengtsson, 2017). Studying how green innovators control the ownership, access, and usage of IP at different green innovation phases will provide insights about using IP to drive sustainability transition. This paper clarifies the role of different IP models, categorized by degree of openness, along the green innovation process, i.e., the research, development/commercialization and diffusion phases and contrasts it across different actor types, namely new ventures, universities, and established firms. Based on content analysis of the qualitative data we collected for 57 green innovations featured in the European Inventor Awards (EIA),[1] including 20 new venture cases, we derive insights about the IP models along the green innovation process phases and the sustainability contributions of new ventures compared to other categories of organization, namely universities and established firms.

The paper is structured as follows. Section 2 provides a review of literature on different IP strategies and related studies reviewing IP in the context of sustainability-oriented green innovations, innovation phases and new ventures. Section 3 describes our methodology. Section 4 presents the results, with examples of cases employing different IP models and differences across innovation phases, technology domains and new venture cases. Section 5 discusses the results and contributions, concluding with implications for future research.

2. Literature review

IP strategies aim to protect and increase the competitive advantage of businesses (e.g., Delerue and Lejeune, 2011; Holgersson and Wallin, 2017; Pitkethly, 2001). The incentive theory of IPR argues that IPR systems (such as patent systems) incentivize innovators. IP acts as a strategic tool to enable firms to attract investment (Oh and Matsuoka, 2016), build competitive advantage (Reitzig, 2007), and to recoup research and development (R&D) investment through internal use (Holgersson and Wallin, 2017) and collaborations with strategic partners (Kim and Vonortas, 2006; Pisano and Teece, 2007). However, on the downside, firms use patents in ways that stifle innovation, using strategies such as: building patent walls to block competing innovations (Cockburn et al., 2010); litigation threat by non-practicing entities – the so called "patent trolls" or "patent sharks"; prevention or delay of inventions from becoming innovations useful to society (Fischer and Henkel, 2012; Henkel and Reitzig, 2008); and exploitation of unequal power advantages in certain countries due to geographical differences in IP regimes, such as variations in patenting procedures and standards (Vimalnath et al., 2021). When patentees of green innovations refrain from sharing (licensing) their patents, the full potential of green innovations to create sustainability impact, such as mitigating climate change, cannot be reached – a scenario described as the "Green Patent Paradox" by Cayton (2020). However, IP sharing literature demonstrates high complexity and moves along the continuum of open and closed IP strategies (Eppinger and Tinnemann, 2014; Vimalnath et al., 2020). Systematic studies demonstrating the relevance of these IP models for sustainability-oriented green innovations creating positive environmental impact are limited. Below, we review the literature on sharing models and green innovations, IP strategies across various innovation phases, and the relationship between new ventures and IP strategies.

2.1. IP sharing models and green innovations

The literature on IP strategy and management indicates that an innovator may choose to (a) keep their invention secret or protected, e.g., using patents (Hannah, 2005; Holgersson and Wallin, 2017) or (b) share it with select strategic partners, e.g., via exclusive or non-exclusive licensing (Bogers et al., 2012; Kim and Vonortas, 2006; Winston, 2006) or (c) share for free to anyone, e.g., via publishing or open source licensing (Baker and Mezzetti, 2005; Ziegler et al., 2014). Accordingly, an IP model can be typologized as closed, semi-open or fully open, based on the degree of openness in the IP ownership, access, and commercial usage rights (Vimalnath et al., 2020) as depicted in Fig. 1. Which of these models is of relevance to create positive environmental impact remains unclear and is investigated in the paper.

In the closed IP model, inventors obtain IPR such as patents, registered trademarks, registered copyrights, and design rights to protect their inventions and prevent imitators from copying the invention for a limited time. Patents incentivize inventors and at the same time mandate public disclosure of the invention (which would otherwise be undisclosed information (trade secret)) as an information source and inspiration for subsequent inventors (Hughes, 1988). In the extreme

[1] https://www.epo.org/learning-events/european-inventor/finalists.html.

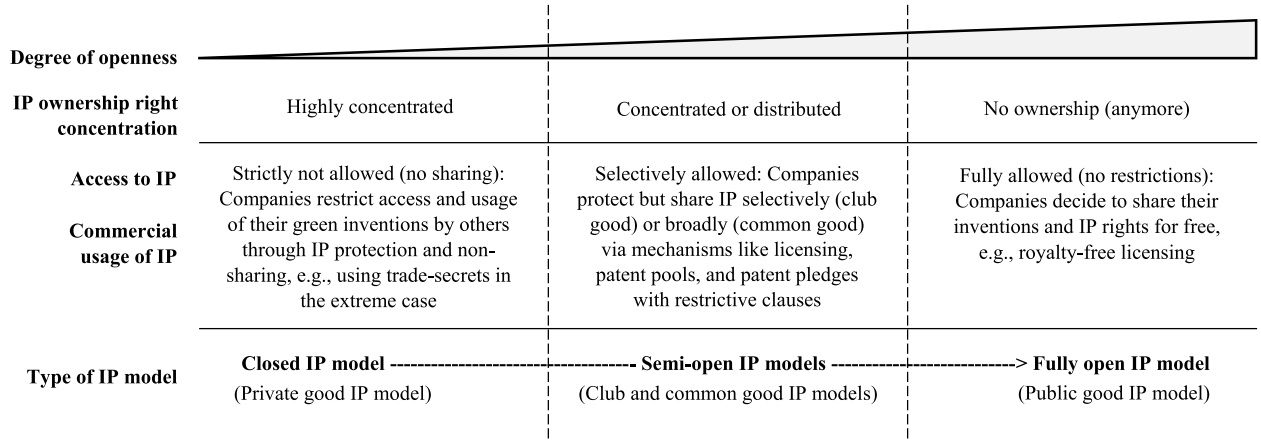

Fig. 1. IP model types (based on Vimalnath et al., 2020; Eppinger and Tinnemann, 2014).

closed IP model scenario, the inventor may not obtain patent protection but rather keep the invention a secret (Crittenden et al., 2015; Hannah, 2005). For sustainability-oriented green innovations, analysis of eco-innovation-related patent data from leading countries such as China, Korea, Japan, the United States and Germany shows an increase in patenting until about 2011–2012 and a decline thereafter (León et al., 2017; Urbaniec et al., 2021). The decline is partly attributed to delays and difficulties in R&D and investment (Cayton, 2020; Fujii and Managi, 2016). Geographical differences in patenting trends across countries are also relevant. For instance, a higher proportion of industry funding for R&D in US universities pushes for patenting, while a higher proportion of government R&D funding in Europe pushes universities towards publication (Shelton and Leydesdorff, 2012). The US allows a grace period between publication and patenting. The lack of such a grace period in many European countries may cause variations in university patenting across countries, more so as publishing is more important than patenting for performance evaluation of university researchers (Geuna and Nesta, 2006). Hence, the IP models that universities adopt across the green innovation phases may vary from those of industrial firms. Unlike universities, firms may adopt trade secrecy in the absence of patents. Lewis (2018) identifies trade secrecy as a way of "evergreening" climate technologies, which hinders the transfer of climate technologies to developing countries, since trade secrecy extends the life cycle of such climate technologies beyond the 20-year protection period offered by patents. While policy initiatives to fast-track patenting applications aim to encourage green innovations, systematic studies assessing the relevance of closed IP models such as patenting and trade secrecy for successful green innovations are scarce.

Embracing the semi-open IP model, firms may voluntarily share all or parts of the IP to a carefully selected set of actors via sharing mechanisms. Example of such mechanisms are exclusive licensing (Liddicoat, 2017; Oster, 1995), non-exclusive licensing (Beyer, 2013; Schmitz, 2007), cross-licensing (Shapiro, 2000), and closed patent pools (Van Etten, 2007). Such mechanisms are designed to restrict other, undesirable actors from accessing the IP. IP sharing happens, for instance, when firms engage in some form of open innovation when they lack complementary assets needed for technology development and commercialization (Teece, 1986) and when in-house technology development, commercialization and diffusion become challenging, costlier and take too much time (Chesbrough, 2006).

The role of licensing for green innovations remains debatable. Chen and Dimitrov (2017) compare licensing decisions by sustainable manufacturers who are lead innovators and traditional manufacturers who are followers or imitators. The authors show that licensing process eco-innovations may pose the risk of the process being copied by follower firms (which is often difficult to prove) and hence reduce competitive advantage for the innovators. Therefore, if the innovator has the complementary assets (e.g., production and marketing assets) needed for commercializing eco-innovations, then a decision to not license these innovations can deter imitation by follower firms. However, Stefan and Paul (2008), using examples from pollution control technology, propose that resourceful firms with research facilities do find selling their technology via licensing fruitful. For firms lacking green technology expertise and competencies, collaborations with green innovators provide access to required capabilities and resources at lower cost (Calza et al., 2017). A recent study of regional networks in China for green patent licensing shows geographical proximity as a critical factor for licensing to facilitate green innovation diffusion (Losacker, 2022). These studies highlight the inconsistencies in the literature about the role of sharing and licensing for environmental sustainability and point toward the need to examine more closely the role semi-open IP models such as licensing and collaborations play in successful green innovations.

In the spirit of a fully open IP model, sometimes firms choose to openly share their IP with others free of cost and without any usage or commercial restrictions. This approach became popular through the open-source software movement, which facilitated large inventor networks, reduced the cost of innovative products and speeded up the innovation process (Benkler, 2008). Royalty-free licensing (e.g., Eco-Patent Commons), patent pledges (Contreras, 2015; Ehrnsperger and Tietze, 2019) (e.g., Tesla's patent pledge), and defensive publishing to provide the IP to the public domain (Henkel et al., 2008) are examples of fully open IP models. Attempts to implement these fully open models for promoting green innovations show varying results. For example, Eco-Patent Commons, a patent pledge initiative for eco-innovations did not facilitate significant diffusion, as measured using patent citations (Hall and Helmers, 2013). Examples of successful open-source hardware initiatives can be found, albeit in other innovation contexts, for example to provide affordable solutions for medical inventions (Niezen et al., 2016), and electronic devices (Open Source Hardware Association, 2021).

2.2. IP strategies and innovation phases

In the context of non-environmental innovation, studies show that IP strategies, including the IP protection and sharing models, vary across innovation phases (Bican et al., 2017; Stefan and Bengtsson, 2017). Stefan and Bengtsson (2017) investigated 340 European manufacturing firms. The authors found the effect of three types of IP protection mechanisms, (formal, semi-formal and informal IP protection) on innovation performance measured in terms of novelty and efficiency vary across the three innovation phases, namely ideation, engineering and commercialization phases.

In the early ideation phase, semi-formal IP protection mechanisms

such as contracts positively affect innovation efficiency but not formal tools such as patents (Stefan and Bengtsson, 2017). In another study, Bican et al. (2017) developed an "Open Innovation Life Cycle" framework to manage IP for open innovations. The Open Innovation Life Cycle consists of three phases, namely preparation (covering ideation and discovery phases of open innovation), operation (covering development, launch and commercialization phases), and termination phases (covering open innovation collaboration wrap-up activities), across three levels namely individual (people), project and firm. The study demonstrated IP strategy and management as an integral part of the open innovation process, emphasizing the value of clarifying IPR ownership and exploitation terms during the early contracting phase to avoid frictions in revenue streams at later phases (Bican et al., 2017). This study did not focus on green innovations and further research is required to explore the role of different types of IP model along the innovation phases of green innovations.

2.3. New ventures and IP for sustainability

Start-ups are an essential driver of innovation processes for sustainability, while sustainability, in turn, is also found to drive innovation processes (Keskin et al., 2013). IPR are particularly relevant for such new ventures, as young ventures are typically wealth constrained and therefore rely on strong IP protection to recoup their investments (Shane and Cable, 2002). Furthermore, studies demonstrate the relevance of new ventures in sustainability processes and the environmental policy of national innovation plans, and indicate that governments have the chance to promote sustainability efforts through appropriate investments in new ventures (Kwon, 2020; Roh et al., 2021). While government investments can be a source of funding for new ventures, obtaining IPR such as patents, though expensive for new ventures, could act as a signalling tool to attract investors. Mann (2004) examined how patents support the financing of ventures in the software industry and found a trade-off between the costs of patents and their benefits. IPR can either support the amortization of R&D investments or hinder innovation as IPR increases market entry barriers (Boldrin and Levine, 2008).

New ventures for green innovations face IP barriers. The IPR systems – particularly the patent system – are sometimes considered as tools that established firms exploit to establish their positions with unsustainable technologies and products rather than for societal benefits. For instance, some build patent fences and sign cross-license agreements to increase entry barriers for new entrants (Chung et al., 2019). Some research results indicate that the patent system particularly supports resource-strong companies (Libaers et al., 2016), discriminating against small and medium-sized enterprises (SMEs), including start-ups that are facing resource and capability constraints (Audretsch et al., 2020). Studies show that established firms, in particular, sometimes patent protect their inventions but do not share these protected inventions with others; hence, the impact of the inventions is limited (Cayton, 2020).

When it comes to IP sharing practices, new ventures, particularly start-ups, have been found to adopt different and more flexible IP licensing strategies than incumbents (Belingheri and Leone, 2017). The extent to which IPR impact green innovation for new ventures is less understood. In this study, we explore IP models adopted by new ventures on green innovations and contrast them with those adopted by universities and established firms.

3. Methodology

The study analyses qualitative data following a general inductive content analysis approach (Thomas, 2003). Our data comprises secondary, qualitative data on 57 green innovations recognized by the European Patent Office (EPO) for their "contribution towards technical progress, social and sustainable development and economic prosperity", through the annual EIA. The case descriptions on the EIA website provide details such as the origin of the invention, type and name of the inventing organization, sector, award category, impact along social, economic and environmental dimensions, inventor's strategic use of their IP, and transcripts of interviews with the inventor. Since the awardees are the inventors themselves, we consider the information provided by the EIA credible and trustworthy.

As the EIAs are awarded for innovations for which inventors have sought patent protection, the sample is biased to patented green innovations. However, several of the patented green innovations in the sample also use other types of IP, such as trademarks, trade secrets and know-how across the phases of the innovation process. The sample is limited in terms of excluding innovations that rely solely on non-patented innovations, such as those only based on trademarks or design rights.

3.1. Sample and unit of analysis

Between the first EIA in 2006 and 2021, the EPO's online EIA database[2] listed 216 entries, including both award winners and finalists. Of the 216 cases, the EPO classified only 29 as green technologies, because this classification was not introduced until 2018. Hence, we read through all EIA data prior to 2018 to identify award winners and finalists with green (i.e., ecological) impact. For classifying pre-2018 EIA data as green innovations we adopted the OECD definition of eco-innovation, as given in section 1. This coding results in 28 additional green innovations, making a total of 57 green innovations. Furthermore, one might note that although the EIA database mainly contains green innovations developed in Europe, the annual award recognizes inventions developed anywhere in the world.

3.2. Data analysis

We adopt a directed content analysis approach (Hsieh and Shannon, 2005). The qualitative secondary data from the EIA website was coded and cross-verified by three experts, following the method used by Jain and Ogden (1999). First, the case texts were read carefully to understand the information available, and the first set of relevant codes was consolidated. For coding the IP models, we referred to the categories by Vimalnath et al. (2020). A detailed description of the coding frame used for classifying IP models is given in the appendix. For coding the innovation process phases we adapted the innovation phases in the framework by Stefan and Bengtsson (2017) and Bican et al. (2017). As in the framework used by Bican et al. (2017), we have combined the development and market entry/commercialization phases into a single phase and separated it from the diffusion phase. This classification closely represented usage variation in IP models across the green innovation phases in the sample studied.

Using consensus among the experts, we developed a coding frame, and coded the case descriptions. Every time a new code emerged, we revised the coding frame, and reread the case descriptions according to the new structure. After three rounds of revisions, the final version of the coding frame included 10 different parent codes grouped under three categories: green innovation process strategies; IP models; and sustainability impact. The categories, parent codes and sub-codes are described in Table 1. The iterative hybrid method of generating coding based on literature as well as case descriptions is common among qualitative content analysis researchers (Rourke and Anderson, 2004).

3.3. Sample description

The sample includes green innovations led by three types of organization, which we classify as new venture, university, and established firm. New ventures include younger firms with age <10 years old and older firms that are more than 10 years old at the time of sampling but

[2] https://inventoraward.epo.org/index.

Table 1
Final coding frame.

Code category	Parent code	Sub-code
Green innovation process	Research phase	Independent research (individual inventors), university/research institution research, in-house industry research (SME, large, start-up), collaborative research (academia–industry/industry–industry/individual–industry/individual–individual collaboration)
	Development/ commercialization phase	Product development and market entry via new venture formation (new venture by the inventor, university spin-off, industry spin-off), via own existing firm, via employer organization, collaboration/partnership
	Diffusion phase	Multiple applications and widespread diffusion via own existing firm, via collaboration/ partnership, or acquisition
IP model	Closed IP model	Patent protection and no sharing, patent sale, secrecy
	Semi-open IP model	Exclusive-licensing, non-exclusive licensing, collaboration/ partnership agreement/contract/ unknown
	Fully open IP model	Patent expiry, free access to patent/invention
	Others – general IP strategies	International patenting, patent monitoring, patent enforcement and litigation, and strategic IP combinations (e.g., patent combined with trade secret to maintain a competitive edge for the invention)
Sustainability impact	Environmental	CO_2 and other greenhouse gas (GHG) emission reduction, energy and material efficiency, 3R (reduce, reuse and recycle)
	Social	Employment, public health, awareness and community development
	Economic	Production capacity, market spread, revenue, cost reduction/ saving

have commercialized the EIA awarded green innovation in their early years through a new venture. We include the latter firms in the new venture category because, in their initial years, they shared similar characteristics with young ventures and the EIA dataset offers historical data about the innovators and IP models adopted by these older firms during their early years. Accordingly, and following the literature on new venture types studied (Gartner, 1985; Rasmussen et al., 2011), we classify new ventures created by individual inventors, university spin-offs and industry spin-offs under the new venture category. University category includes private and public universities and publicly funded research institutes. Table 2 presents the distribution of the sample across the three categories.

Out of the 57 cases, 35% (20 cases) falls under the new venture category, 18% (10 cases) under universities and a majority of 47% (27 cases) under the established firm category.

Not surprisingly, because the EIA is a European prize by the EPO, green innovations from Europe dominate the sample. These represent 78% in the established firm category, 85% (including the UK) in the new venture category and 70% in the university category.

Fig. 2 depicts the yearly distribution of the sample of 57 EIA awards and the origin of the green innovations across the three categories. The figure shows that about 60% of the new venture cases featured after 2015, the year in which the United Nations General Assembly adopted the Sustainable Development Goals (SDGs).

Table 2
Sample distribution across organization categories.

Organization category	Description and classification criteria	Cases	Geographical coverage
Established firm	Green innovations originating from existing/ established firms.	47% (27 cases)	Europe (21), Japan (4), USA (1), Canada (1), Korea[a] (1)
New venture	Green innovations originating from and/or commercialized through new ventures, including new ventures by individual inventors, university spin-offs and industry spin-offs (based on Gartner, 1985).	35% (20 cases)	Europe (17), USA (2), Canada (1)
University	Green innovations originating from and commercialized by universities, including those developed in collaboration with one or more industry partners.	18% (10 cases)	Europe (7), USA (2), Australia (1)

[a] The Korean invention in collaboration with Austria (Europe).

Fig. 3 shows distribution by technology domain from 2006 to 2021. The figure reveals that climate change mitigation technology (often abbreviated as CCMT) related to energy dominates the sample (37%), followed by awards for materials/plastic/packaging technology (18%).

4. Results

This section reports the results from mapping the IP models to the three green innovation process phases (research, development/ commercialization, diffusion), contrasting the findings for the three organization categories (new ventures, universities, established firms). Using examples from the cases we illustrate how new ventures, universities and established firms use different IP models across the three innovation phases to achieve environmental impact (part of societal impact) and economic impact. Table 3 presents the adoption of IP models (closed, semi-open, fully open) in the three green innovation process phases across the three organization categories. Within each innovation phase, different organizations adopt different modes or mechanisms to execute that phase. For example, the research phase can consist of research done by a firm in-house, a research institution such as university, or an independent inventor. Fig. 4 maps the choice of IP models across the green innovation phases for the overall sample (Fig. 4a), new ventures (Fig. 4b), established firms (Fig. 4c) and universities (Fig. 4d).

The analysis of all 57 cases reveals that green innovators in our sample adopt five IP models: one closed IP model type namely (i) closed protective IP model (no sharing); three semi-open IP models namely (ii) exclusive licensing model (semi-open type), (iii) non-exclusive licensing model (semi-open type), and (iv) collaboration and partnership model (semi-open type); and one other model namely (v) strategic mix of IP assets. Green innovators seem to favour certain IP models over others and their benefits seem to vary across the green innovation process phases.

About 40% of the cases adopted a closed IP model of patenting the invention, thus protecting the key invention without sharing this IP with others during the development/commercialization phase. In two of the cases, the patents protecting the core technology expired and are now freely available for anyone to use even for commercial purposes, thus unintentionally resulting in a fully open IP model, since the innovators did not proactively pursue an open IP model. Overall, 56% of the green innovation cases adopted some form of semi-open IP model in one or more of the innovation process phases. Among the semi-open models, licensing appears to be the prominent IP sharing mechanism,

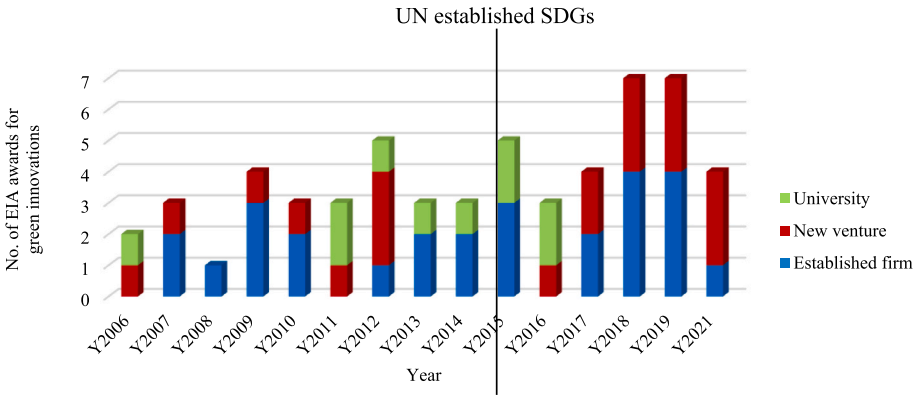

Fig. 2. Yearly distribution of EIA awards across organization categories, time period 2006–2021 (n = 57).

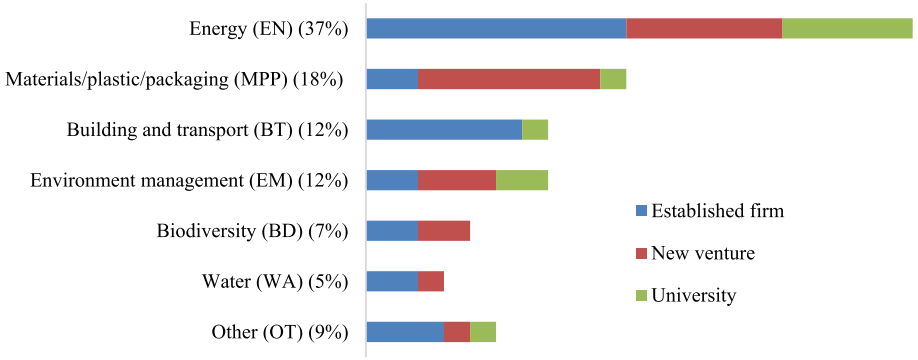

Fig. 3. Distribution of EIA awards across organization categories by technology domain, time period 2006–2021 (n = 57).

particularly non-exclusive licensing. Of the 17 green innovators that adopted a licensing model, the large majority (77%) adopted a non-exclusive licensing model. In the semi-open IP model category, another frequently observed model is collaboration or partnership, which typically involved some form of agreement or contract (the IP terms were not specified clearly in the data).

While around 20% of cases adopted semi-open IP models in the research phase, about 34% adopted semi-open IP models during the development/commercialization phase, and 42% in the diffusion phase. In other words, the dominance of the closed IP model decreases along the innovation phases (81% in the research phase, 53% in the development/commercialization phase, and 40% in the diffusion phase). Thus, overall, we find from the analysis that the probability for green innovators to adopt IP models with some degree of openness increases along the innovation process phases.

Results in Table 3 comparing the IP models adopted by the three organization categories (new ventures, universities and established firms) demonstrate that established firms predominantly perform in-house R&D, file for patent protection of their green invention and exploit the invention commercially without sharing with others. In contrast, the use of closed models by new ventures appears more during the research phase. About 80% of the new ventures in our sample did not share their IP with others in the research phase but did share with others in later process phases, predominantly through non-exclusive out-licensing and collaborative partnership agreements. Likewise, universities in our sample shared their IP with industry partners during the development/commercialization and diffusion phases, mostly via exclusive out-licensing or non-exclusive licensing of the green technology patents. Thus, new ventures and universities seem to use their IP strategically differently from established firms (see section 4.1. for details about IP models adopted by different organization types within each innovation phase).

Results from analysing the sample for likely variations in IP model preferences across the seven technology domains (Table 4) show that the propensity to adopt semi-open IP models (non-exclusive licensing and collaboration in particular) seems to be higher than adoption of closed or fully open IP models in technological domains such as water (WA) – 67%, materials/plastic/packaging (MPP) – 60%; environment management (EM) – 57%; and energy-related CCMT (EN) – 57%.

Cases in environment technology domains such as environment management, materials/plastic/packaging and CCMT adopted semi-open IP models, with non-exclusive licensing being the most commonly adopted model, followed by exclusive licensing and collaboration. Firms adopted these models for development and commercialization in the energy sector.

4.1. IP models in the research phase of green innovation

The EIA cases demonstrate multiple sources of green inventions in the research phase. Among the 57 green innovations, 82% have roots either in research by firms through in-house R&D (42%), universities (26%), or individual inventions (14%). Only around 18% of innovations originated in collaborative research settings. About 40% of new ventures originated in work done by individual inventors, followed by 30% of ventures as university spin-offs based on university research, and about 20% from collaborative research. Likewise, established firms and universities had majority of their research done in-house (internal company R&D and university research respectively). Consequently, results demonstratethat irrespective of organization category, all three – new ventures, universities, and established firms – research green technologies and predominantly adopt closed IP models during the research phase, both to protect their inventions and to harness other benefits, explained below.

New ventures appear to adopt closed IP models to attract investors

Table 3
IP models across green innovation process phases and organization categories.

	Innovation process phases										
Innovation modes/ mechanisms	**Research phase**	**% Established firm cases**	**% New venture cases**	**% University cases**	**Development/ commercialization phase**	**% Established firm cases**	**% New venture cases**	**% University cases**	**Diffusion phase**	**% Established firm cases**	**% New venture cases**	**% University cases**
	In-house	82%	10%		Employer organization	78%			Collaboration/ partnership	30%	55%	50%
	University research		30%	91%	New venture		100%		In-house efforts	62%	25%	
	Collaborative research	18%	20%	9%	Collaboration/ partnership	4%		60%	Acquisition by larger company	4%	5%	
	Independent research		40%		Own existing firm	19%			Not available/ not explicit	4%	15%	50%
	Total	100%	100%	100%	Not available/not explicit			40%	**Total**	100%	100%	100%
					Total	100%	100%	100%				
IP models/ sharing mechanisms	**Research phase**	**% Established firm cases**	**% New venture cases**	**% University cases**	**Development/ commercialization phase**	**% Established firm cases**	**% New venture cases**	**% University cases**	**Diffusion phase**	**% Established firm cases**	**% New venture cases**	**% University cases**
	Closed IP model	**81%**	**80%**	**80%**	**Closed IP model**	**74%**	**45%**		**Closed IP model**	**59%**	**35%**	
	Patent protection/no sharing	*81%*	*80%*	*80%*	*Patent protection/no sharing*	*74%*	*45%*		*Patent protection/ no sharing*	*52%*	*30%*	
	Semi-open IP models	**19%**	**20%**	**20%**	**Semi-open IP model**	**19%**	**50%**	**60%**	*Patent sale*	*7%*	*5%*	
	Collaborative agreement/ contracts	*15%*	*20%*	*20%*	*Collaborative agreement/ contract*	*15%*	*25%*	*10%*	**Semi-open IP model**	**30%**	**50%**	**50%**
	Exclusive in-licensing	*4%*			*Non-exclusive out-licensing*	*4%*	*25%*	*20%*	*Non-exclusive out-licensing*	*11%*	*40%*	*20%*
	Total	100%	100%	100%	*Exclusive out-licensing*			*30%*	*Collaborative agreement/ contract*	*19%*	*10%*	
					Not available/not explicit	**7%**	**5%**	**40%**	*Exclusive out-licensing*			*30%*
					Total	100%	100%	100%	**Fully open IP model**	7%		
									Patent expired	7%		
									Not available/ not explicit	7%	15%	50%
									Total	100%	100%	100%

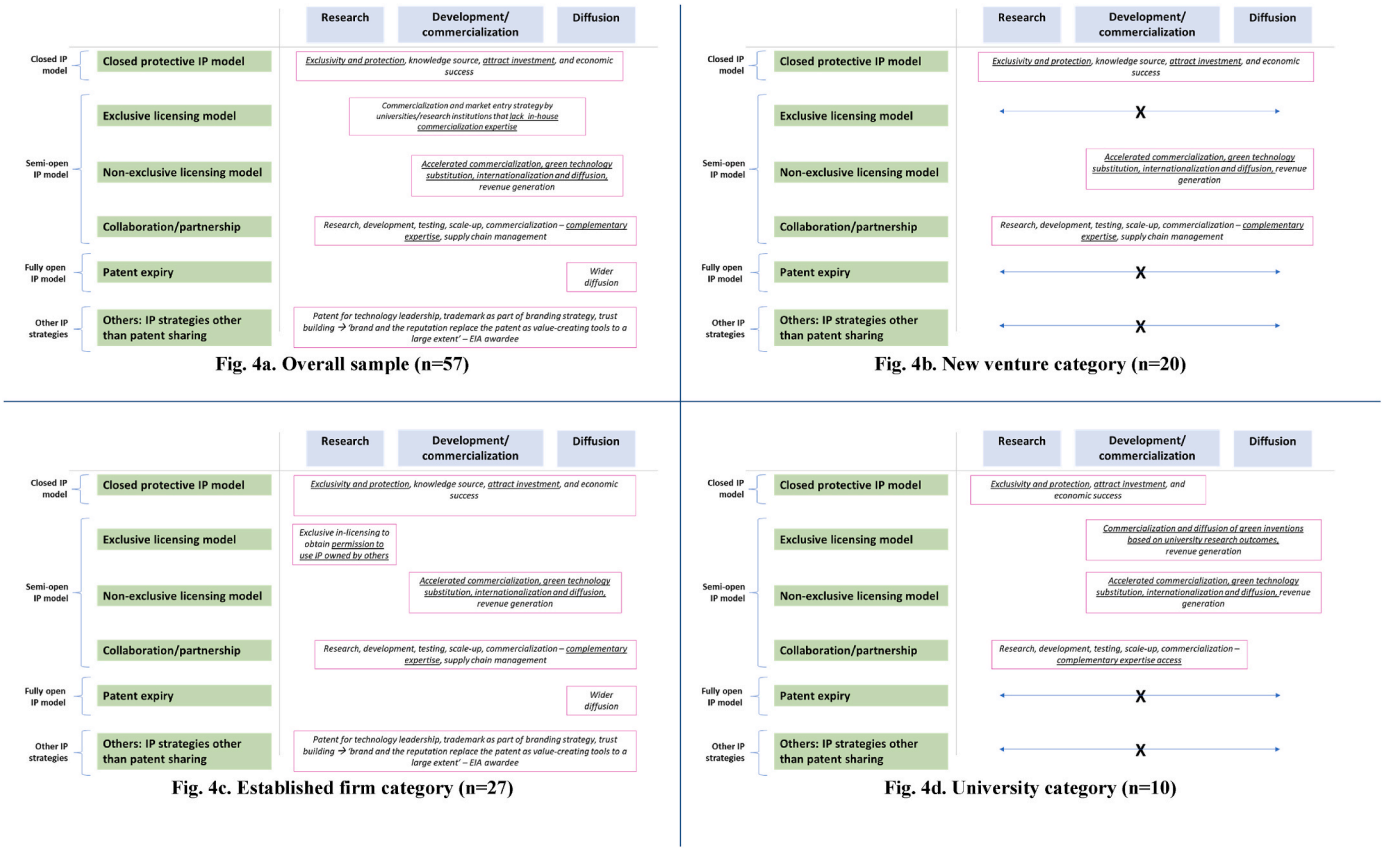

Fig. 4. IP models across green innovation process phases for organization categories.

Table 4
IP models across seven technology domains (n = 57).

IP model category	Technology domains*						
	EN	MPP	BT	EM	BD	WA	OT
Closed IP model	**38%**	**40%**	**57%**	**43%**	**50%**	**33%**	**20%**
Protective and no sharing	*33%*	*40%*	*43%*	*29%*	*50%*	*33%*	*20%*
Patent sale	*5%*		*14%*	*14%*			
Semi-open IP model	**57%**	**60%**	**43%**	**57%**	**50%**	**67%**	**60%**
Collaboration and partnership	*24%*	*40%*	*29%*	*14%*	*25%*	*33%*	*40%*
Non-exclusive licensing	*29%*	*20%*		*14%*	*25%*	*33%*	*20%*
Exclusive licensing	*5%*		*14%*	*29%*			
Fully open IP model	**5%**						**20%**
Patent expiry	*5%*						*20%*
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Key*: BD = Biodiversity; EM = Environment management; BT = Building and transport; EN = Energy; MPP = Materials/plastic/packaging; WA = Water; OT = Other.

during the subsequent innovation phases. For instance, Esben Beck, a Norway-based inventor, developed a submersible robot to solve the problem of parasite impact on the salmon harvest. The inventor patented the machine in the research phase in 2010, established a start-up named Stingray Marine Solutions and used patents to attract investors for later innovation phases, particularly for development/commercialization.

Similarly, established firms with in-house R&D seem to adopt closed IP models for protection and economic success and use patents as a knowledge source during the research phase. These firms use patents to protect the green inventions, gain competitive advantage and economic success, and show little tendency to share the patents with others. They also use patents as a source of information to learn about green technologies developed by others. For instance, two inventors from the EREMA Group, a large Austrian-based firm (founded in 1983), developed and built state-of-the-art recycling machines that "move, sort and filter plastic matter, delivering high-quality pellets for use to create new products". The company patented the core technology of this in-house invention, called the Counter Current Technology and considers having such protection as crucial for economic success. As of 2019, EREMA is a world leader with over 6000 of EREMA's recycling systems operating in around 108 countries and producing 14.5 million tonnes of plastic pellets every year which would otherwise go to landfill waste (EREMA, 2019). In the words of co-inventor Klaus Feichtinger:

> "For economic success, patents play a major role. They provide inspiration, and are the source of new ideas. Through patents you can see how problems are solved by other people and come up with new concepts, new ways to solve challenges."

Furthermore, as commented by co-inventor Manfred Hackl, "The [patents] have helped us in our efforts to encourage the plastics industry to move towards the circular economy."

Firms also use patent enforcement as a way of maintaining exclusivity and competitiveness. For example, the German engineer Stefan Lehnert, the inventor of an innovative roof and cladding system using energy efficient, highly durable, light and adaptable plastic, stated:

> "It is not only about competitors, but also about potential customers. We find out rather easily, due to our market position, whether a new project is trying to infringe our patents, and we will by no means be satisfied with a licensing contract. If they go through with the project, we will sue and we will demand that the project be built back. We are, however, of course aware that some parties which we could sue could be potential customers. This is why we will address the problem as early as possible, in advance of project realisation. What definitely helps, is to be the market leader. Being technology leader without market power would be considerably more difficult."

Unlike new ventures and established firms, universities tend to adopt closed IP models to attract industry partners who will find value in exploiting university inventions during later innovation phases. For instance, the company NEREDA that commercializes a process for treating and purifying wastewater was founded based on the patents developed by Prof. Mark van Loosdrecht and his team at Delft University of Technology (Netherlands). According to Prof. van Loosdrecht, "[a patent] proves substance and ownership. Without a patent, no private firm would seriously start to (co-)develop".

4.2. IP models in the development/commercialization phase of green innovation

In the development/commercialization phase, about half of the new ventures in the sample continued with closed IP models, but the other half adopted semi-open IP models. Those new ventures that continued with closed IP models in the development/commercialization phase primarily focused on attracting investment in order to do green technology development/commercialization. In the Norwegian example above, after venture creation, the inventors developed "initial prototypes and raised more than €4 million to launch the product" during the development/commercialization phase. Thus, adopting a closed IP model helped the inventors and "Norway's €6.4 billion-salmon industry" to eventually become a global market leader. Closed IP models thus can help new ventures to attract investment for accelerating the development and scale-up of green technology that solves sustainability challenges.

A further benefit for new ventures in adopting closed IP models during the development/commercialization phase is getting the first-mover advantage in gaining investment from incumbent firms from a complementary industry. For example, in a new venture case, a closed IP model during the development/commercialization phase helped a firm in the boat paint sector to become a first mover by raising investment from an established player in the complementary textiles industry for product development and market launch. Rik Bruer, a Dutch inventor of an environmentally friendly alternative to toxic paint said,

> "patent was key to the business development: It gave me credibility and helped me to get investors on board".

Through this invention, the fuel efficiency of boats improved by up to 40% and "prevents the growth of algae, barnacles and mussels on boat hulls". Similarly, in a new venture case for water conservation technology, the inventor adopted a closed IP model when he wanted his start-up to enter a market dominated by established incumbents. Orbital Systems was founded in 2012 by Mehrdad Mahdjoubi (Sweden). The inventor of "Oas", a closed-loop shower system, adopted a closed IP model obtaining patent protections in around 10 countries[3] not only to protect his company's position in a market dominated by established companies, but also to gain the confidence of larger investors in all innovation process phases. Mehrdad surmised:

> "… when we came with new technology it's really important for us to have a patent on this because that protects us as being the newcomers, the innovators that is basically our biggest leverage point."

Even more than new ventures, established firms continued with closed IP models and engaged in their own exploitation of the IP protecting their green invention. Unlike new ventures and established firms, the majority of universities (60%) shifted to semi-open IP models for development/commercialization (market entry). Results indicate that semi-open IP models, particularly exclusive patent licensing, seem to be a common market entry strategy for universities to commercialize their green innovations, as universities generally lack in-house commercialization expertise. The following two examples illustrate this.

With the aim of increasing biodiversity, at the Polytechnic University of Valencia (Spain) Menéndez Díaz Josep Ramon Medina and Esther Gómez-Martín invented "Cubipod", an unusually shaped concrete block for dissipating breakwaters that reduces erosion and provides better coastal protection. In the research phase, the university patented the invention that was not commercial ready. The university then adopted a semi-open IP model exclusively licensing the invention to an industry partner, SATO. SATO developed a reusable mould for producing the Cubipod blocks "in an efficient, cost-effective and flexible manner". Together, this university–industry exclusive licensing model has enabled the protection of several ports. In the development/commercialization phase, "in 2018, the company was awarded a EUR 44.6 million contract to expand the port of Agaete in Gran Canaria". In the diffusion phase, "in 2019, the company won a contract valued at EUR 8.1 million for the construction of the southern outer sea wall of Naos, in the Port of Arrecife in Lanzarote. These projects have meant the construction and installation of more than 33,000 Cubipods of various sizes from 3 tons to 45 tons".

The second example is a renewable energy invention for easier and cheaper solar cell production developed by Jörg Horzel and his team from IMEC, a nanotechnology research institute in Belgium. In the development/commercialization phase IMEC adopted a semi-open IP model, exclusively licensing the technology to one of IMEC's spinoffs. The green innovation created a significant impact in the solar energy sector. With the help of this technology solar energy production has increased by an average of 40% per year worldwide since 2000.

The three exclusive licensing cases in our sample relate to inventions that originated at universities or research institutes. In rare cases, established firms also engaged in collaboration/partnership (semi-open IP model category) with other established firms to enter a market. For instance, Ballard Power Systems is a Canadian company that developed electrochemical fuel cell technology. It adopted a collaboration approach, partnering with "big players" in the development/commercialization phase to get the technology "on the road".

4.3. IP models in the diffusion phase of green innovation

In our sample, semi-open IP models, particularly non-exclusive licensing, comprised the prevalent IP model in the green innovation diffusion phase, particularly among new ventures. The following examples illustrate cases adopting these IP models to create sustainability impact through wider diffusion of green innovations.

New ventures adopted non-exclusive licensing as a form of semi-open IP model to expand the green innovation impact to international

[3] According to the patent list retrieved by the authors in the Espacenet database (https://worldwide.espacenet.com/) following the link provided for the patent on the EIA website.

markets. One example is the invention by the US entrepreneurs Eben Bayer and Gavin McIntyre in the materials and packaging sector. The inventors developed an environmentally friendly biomaterial alternative to plastics that delivers a strength-to-weight ratio comparable to many plastic-based products and is fully degradable in 45–180 days. As of 2019, Ecovative Design, the company co-founded by these inventors, had raised investments and grants of about EUR 22.1 million and employed around 45 people. The inventors have sought patent protection in 31 countries and adopted a semi-open IP model in the diffusion phase: a non-exclusive licensing approach that helped them expand internationally. According to McIntyre:

> "Since we created a new domain in material science, patents have become incredibly important to our organisation, allowing us to focus on our ongoing research efforts while extending the reach of our products through licensing partnerships internationally".

We also found new venture IP licensing firms adopting non-exclusive licensing as the core business model. These green innovators used non-exclusive licensing approaches (semi-open IP model) as a business model for revenue generation. Some of these later started their own manufacturing units, but initially relied on licensing revenues, possibly to generate funds to grow the company organically. The following two cases provide examples of how green innovators developed licensing-based business models.

WhalePower Corporation, a Canadian firm, invented and patented turbines and fans inspired by nature, particularly the "bumpy flippers of humpback whales". According to the EIA website, WhalePower "operates as a virtual intellectual property firm, licensing the designs to other companies wanting to use the technology in their particular areas of expertise". The company commercialized a first product used in industrial and commercial fans and blowers. The global market for these products is estimated to be worth some EUR 8.5 billion in 2022.

A second example concerns a UK-based venture named Lontra. Operating in the energy sector, the company developed and filed patents for an innovative energy-saving rotary air compressor technology. In 2014, Lontra closed a deal with the Swiss pump manufacturer Sulzer, reportedly worth EUR 717 million, to supply the technology to wastewater treatment plants. The company adopted a non-exclusive licensing approach (semi-open IP model) and operated as an intellectual property firm to license Blade Compressor technology for use in various industries.

In the diffusion phase, established firms also collaborate/partner with other established players to increase the diffusion of their green inventions and to sustain their leadership position. For example, Ballard Power Systems, the Canadian electrochemical fuel cell technology company discussed in section 4.2, partnered with two international automotive companies (Daimler-Benz and Ford) for mass production. The collaboration resulted in a spin-off company, Automotive Fuel Cell Cooperation, which later purchased Ballard's automotive division including the IP in 2007 "to expand their leading position in fuel cell technology".

A higher proportion of established firms adopted collaborative/partnership approaches in the green innovation diffusion phase than in the other two phases. Firms also adopted a strategic mix of different IP types (e.g., patents and trademarks) as a strategy to prolong the diffusion phase, as they find patent value deteriorating when it expires but trademark value increasing as the brand builds.

Universities continued to adopt semi-open models – exclusive licensing and non-exclusive licensing – in the diffusion phase, as in the development/commercialization phase.

5. Discussion and conclusion

The need to incentivize and diffuse green innovations for sustainability/climate change adaptation and mitigation purposes was made more pressing by the 2019 UN Climate Change Conference. At national or governmental level, new departments for "environmental and social responsibility" are being created and discussions on the use of IP as a tool to create sustainable impact through collaboration have started in recent years. At the organization level, however, the role and use of IP for environmental impact remains unclear. This research analyses the IP models adopted along three innovation process phases namely research, development/commercialization, and diffusion for a sample of 57 green innovations featured in the EIA listing. We contrast the IP models adopted by new ventures with those of universities and established firms along these phases. With this evidence-based study, we make the following contributions.

First, on the question of whether IP protection hinders or facilitates green innovation, our analysis shows that the economic incentive impact argument speaking in favour of the IPR systems (Holgersson and Wallin, 2017; Oh and Matsuoka, 2016; Reitzig, 2007) remains valid also in the context of green innovations, since most of the firms we studied mentioned IP protection as critical. Notwithstanding recent initiatives pushing for completely free and open IP models (e.g., patent pledges, open source licensing), this study demonstrates that IP rights such as patents remain an important tool for innovation in various green technology domains, predominantly during the early innovation process (research) phase and irrespective of whether the innovator is a new entrant, established firm or university. New ventures use patents mainly to attract investment, universities for attracting industry partners and established firms for competitive advantage, among other reasons. We have observed closed IP models mostly in the research phase, whereas, the diffusion phase is typically characterized by semi-open IP models in which the organization shares their IP with others. This leads to our second contribution as follows.

As our second contribution, we provide empirical evidence that organizations adopt different IP models and change them along the innovation process phases to bring green innovations to the market and subsequently create wider diffusion and sustainability impact while maintaining their competitive advantage. Organizations start sharing their IP selectively, in other words adopt semi-open IP models with an increased degree of openness, as they move along the innovation process phases. The timing and the extent to which organizations share their IP vary. While universities adopt semi-open models and share IP (exclusively or non-exclusively) during the development/commercialization phase, new ventures share their IP increasingly non-exclusively during the diffusion phases, while keeping the IP predominantly closed during the research phase. Established firms predominantly keep their IP closed in all three phases, but share relatively more widely through collaboration or non-exclusive licensing during the diffusion phase. While we do find evidence to support Cayton's theory of the "Green Patent Paradox" (Cayton, 2020), we also find that the time element (phase) is critical when discussing the Paradox. We find supporting evidence for the Paradox during the development/commercialization phase in particular, when established firms predominantly keep their IP closed, but universities and new ventures start to share their IP with others. But during the diffusion phase, the Paradox starts to fade among established firms, who find themselves in a stable position for sharing their IP with others. Hence, our findings also provide support to the argument of IP sharing being essential for creating environmental sustainability impact, but only during later innovation phases.

Thirdly, deriving from the open innovation literature, we find that organizations keep their IP closed during research phase, which allows them sufficient time and opportunity to clearly define their background IP (IP owned by the organization before entering into the open innovation collaboration) to facilitate collaboration in subsequent phases. Studies have reported collaboration becoming difficult as IPR affects the motivation to license, while other factors such as "favourable market conditions, favourable investment climate, scientific capabilities, infrastructure and human capital" seem to have similar or even greater weight in the decision to enter into licensing agreements (UNEP report "Patents and clean energy," 2011). Although consolidated efforts to

collaborate (e.g., Eco-Patent Commons, GreenXchange, and WIPO Green) were started to lower transaction costs for finding and negotiating contracts to use or transfer green innovations, their success remains to be proven. Prior analysis indicates that the Eco-Patent Commons mainly failed because companies did not pledge their most important patents and did not offer any service for transferring patented technology (Contreras et al., 2019). The GreenXchange platform (Ghafele, 2012) and its licensing model appeared as a more feasible solution despite the lack of resources to achieve the desired success of the initiative. None of the three initiatives provided for a system to track the use of the licensed patents (and thus enable impact assessment) and lacked effective management. Nevertheless, they are relevant as first attempts to signal the need for experimenting with IP models to accelerate sustainability transitions. Noting that these platforms lacked focus – they did not target particular types of organizations – our findings suggest, in contrast, a need for collaborative IP sharing platforms that connect universities, new ventures, and established firms particularly during the development/commercialization stage. Our findings also support the view that IP sharing mechanisms should be tailored towards such collaborations between new entrants and incumbents (Eppinger et al., 2021).

Fourthly, we contribute by providing insights about the reasons a green innovator decides to share IP during different innovation phases. Overall, in our sample we find that companies choose semi-open IP models with a fairly high degree of openness, i.e., non-exclusive licensing for three reasons: for entering new markets (including their first); to accelerate diffusion of green innovations; and to generate revenues by adopting a licensing-based business model. Semi-open IP models with a fairly low degree of openness, i.e., exclusive licensing, on the other hand, appear to be adopted by green innovators lacking commercialization expertise, such as universities, research institutes or individuals to bring their inventions to the market. Licensing university IP to industry (Bercovitz and Feldman, 2006) and sharing related knowledge (Han, 2017) has been discussed as one of the core elements in university–industry relationships. Our findings support this argument. One may, however, mention a particular risk emerging from exclusively licensing technology with potentially large social and environmental impact to a specific company. If the technology has potential multiple applications to benefit society, but the exclusive licensee uses only one or few of them, the technology is prevented from achieving its full potential impact. Considering that universities are a key driver for green technology research (Purcell et al., 2019), future research and initiatives should focus on ways to encourage broad non-exclusive sharing of university IP for green innovations. When universities need exclusivity and exclusive licensing to attract funding and commercialization partners respectively, universities can ensure an option to access the licensed IP again if the start-up fails (bankruptcy) in order to enable the university to re-license the IP to another entity. Furthermore, the practice of humanitarian licensing or socially responsible licensing practiced by some universities for pharmaceutical and medical technologies (European Commission Directorate General for Employment, Social Affairs and Inclusion and Organisation for Economic Co-operation and Development, 2015; Mimura, 2009) could be a relevant IP model for universities and research institutes to diffuse green technologies.

In summary, open innovation research argues that firms benefit from "striking the right balance between sharing and protection" (Henkel, 2006). In the context of green innovation, we also find inventors distinguishing between "protective" and "sharing" aspects of IP and choose to tie them together for better economic, environmental and societal benefits. The coexistence of exclusivity and shared use of IP is evident in IP licensing models. We find both these strategies essential for green innovations to proliferate, but the balance is achieved by aligning the IP model choices with the requirements and objectives in each phase of the innovation process. Patents, thus, can facilitate sustainability effectively when licensed and complemented with relevant know-how, as proposed in Japan's Green Technology Package Program (GTTP) (Consilvio, 2011). Protective aspects of patents can encourage green innovators to further develop/commercialize their technologies and licensing can help in the diffusion phase.

Our analysis does not provide any evidence of successful green innovators that create substantial environmental and social impact by employing fully open IP models. One of the reasons for this finding might be the nature of our dataset. Where universities use publications as a form of fully open IP to share their inventions (e.g., via open access publishing), those innovators are likely to not be covered in our sample. Notably, there are new ventures adopting fully open IP models, such as open hardware sharing, for example in the energy and consumer electronics sectors, which are not included in this research due to our sampling strategy that used patent-protected green innovation as a starting point. These initiatives and their sustainable impact would be worth exploring in further studies. Overall, we conclude that successful green innovators adopt and combine different IP models in the different innovation process phases. Future research might investigate in detail the paths these firms take with regards to changing their IP models along the innovation process, that is, analysing what Tang and Tietze (2021) call "IP strategy trajectories".

Results from analysing the adoption of different IP models across seven technology domains indicate that IP models vary across technology domains. Therefore, macro-level initiatives and policy considerations should pay attention to technology domain sensitivities when devising a macro-level IP management setup for green innovations, such as having technology domain-specific posts within the IP specialist workforce to support IP protection in the research phase and sharing during the development and diffusion phases for IP-intensive technology domains, but creating collaborative platforms for use in the early research stage for less IP-intensive domains.

Our findings highlight that IP policy level discussions thus should move beyond incentivizing innovations through exclusivity towards facilitating IP sharing and collaborative approaches to IP for sustainability. Very few IP-related policy initiatives exist on this front. Related examples include the proposed "right to repair" directive by the European Union which requires manufacturers to disclose their proprietary information and IP which would otherwise have remained a trade secret or not accessible to enable customers to repair products (European Commission, 2015) and the UK's implementation of fast-track patent examination route to green/sustainability focused inventions. But these initiatives do not strongly advocate the role of IP sharing mechanisms such as the licensing mechanisms for sustainability. Policy orientation towards IP sharing and "shared value" perspectives on sustainability is needed for inculcating the sharing mindset within firms innovating green technologies and to enable system-wide sustainability impact.

As with all studies, this one is not free of limitations, and some have been mentioned already. First, our study is limited to data from one source i.e., the EIA, and the sample analysed in this study is not representative of a larger population, but rather biased to a selected group of highly successful green innovations, i.e., those awarded with an EIA by the EPO. Furthermore, the data includes only patent-protected green innovations and hence the study provides little insight on fully open IP models and those that do not involve registered IP rights. Nevertheless, the empirical evidence from this research provides insight on the uses of different IP models across innovation process phases and by different types of green innovators – new entrants, established firms and universities. Further studies using primary data from different sources will be useful.

Funding support

This paper is developed as a part of the research project IPACST. IPACST is financially supported by the Belmont Forum and NORFACE Joint Research Programme on Transformations to Sustainability, which is co-funded by DLR/BMBF FONA-SÖF 01UV1812A and 01UV1812B, Germany; GCRF, United Kingdom; ESRC (ES/S008322/1), United

Kingdom; VR 2017–06439, Sweden; and the European Commission through Horizon 2020.

Disclaimer

The EPO has provided us with support in finding all relevant information on the web, but was neither involved nor provided support in the analysis or preparation of the paper.

CRediT authorship contribution statement

Pratheeba Vimalnath: Conceptualization, Investigation, Data curation, Formal analysis, Writing – original draft, Writing – review & editing. **Frank Tietze:** Conceptualization, Writing – original draft, Writing – review & editing. **Akriti Jain:** Investigation, Writing – original draft, Writing – review & editing. **Anjula Gurtoo:** Conceptualization, Writing – review & editing. **Elisabeth Eppinger:** Writing – review & editing. **Maximilian Elsen:** Writing – review & editing.

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.

Data availability

Data will be made available on request.

Acknowledgements

The authors acknowledge Anna Quincey and Becca Clarke for their help in the initial round of data collection and coding; anonymous reviewers and participants of various conferences who provided valuable feedback to improve the paper; Karen Haynes for providing language help and for proof reading the article.

Appendix. IP model categorization frame (based on Vimalnath et al., 2020)

IP model	Description
Closed IP model	
Patent protection and no sharing	The inventing entity owns the patent and brings the technology to the market without sharing the rights with any external third parties. In this case, the patent owner restricts third parties from commercially exploiting the invention. Cases with no mention of licensing and any kind of collaboration for R&D, market entry or diffusion are coded as belonging to this IP model.
Patent sale	The inventing entity owns the patent and the ownership was transferred to another entity during patent sale or as a part of acquisition of the inventing entity.
Semi-open IP model	
Patent licensing	The inventor owns the patent rights but has shared the rights for commercially exploiting the invention to one or more external entity through some kind of license agreement. Licensing can be exclusive or non-exclusive.
Exclusive licensing	The right to commercially exploit the invention is given to a single entity. Cases with explicit mention of an exclusive license are coded under the exclusive licensing model.
Non-exclusive licensing	The right to commercially exploit the invention is given to multiple entities. Cases with explicit mention of licenses to multiple entities or mention of licensing in the context of partnerships or collaborations are coded as non-exclusive licensing.
Collaboration or partnership agreement or contracts	If some kind of collaboration is mentioned within the case description, but without mention of any kind of patent-sharing mechanisms or licensing, then the case is coded under this category.
Fully open IP model	
Free access to IP/patent expiry	The inventor allows anyone to use the IP free of charge without any commercial or use restrictions. Patents upon expiry fall under the fully open IP model.

References

Abbott, F.M., 2018. Intellectual property rights and climate change: interpreting the TRIPS agreement for environmentally sound technologies. J. Int. Econ. Law 21, 233–236. https://doi.org/10.1093/jiel/jgy011.

Aboelmaged, M., Hashem, G., 2019. Absorptive capacity and green innovation adoption in SMEs: the mediating effects of sustainable organisational capabilities. J. Clean. Prod. 220, 853–863. https://doi.org/10.1016/j.jclepro.2019.02.150.

Ali, W., Jun, W., Hussain, H., Khan, N.A., Younas, M.W., Jamil, I., 2021. Does green intellectual capital matter for green innovation adoption? Evidence from the manufacturing SMEs of Pakistan. Journal of Intellectual Capital ahead-of-print. https://doi.org/10.1108/JIC-06-2020-0204.

Alonso-Martínez, D., 2018. Social progress and international patent collaboration. Technol. Forecast. Soc. Change 134, 169–177. https://doi.org/10.1016/j.techfore.2018.06.001.

Audretsch, D., Colombelli, A., Grilli, L., Minola, T., Rasmussen, E., 2020. Innovative start-ups and policy initiatives. Research Policy, Innovative start-ups and policy initiatives 49, 104027. https://doi.org/10.1016/j.respol.2020.104027.

Baker, S., Mezzetti, C., 2005. Disclosure as a strategy in the patent race. J. Law Econ. 48, 173–194. https://doi.org/10.1086/426879.

Belingheri, P., Leone, M.I., 2017. Walking into the room with IP: exploring start-ups' IP licensing strategy. Manag. Decis. 55, 1209–1225. https://doi.org/10.1108/MD-04-2016-0227.

Benkler, Y., 2008. The Wealth of Networks: How Social Production Transforms Markets and Freedom, the Wealth of Networks. Yale University Press. https://doi.org/10.12987/9780300127232.

Bercovitz, J., Feldman, M., 2006. Entrepreneurial universities and technology transfer: a conceptual framework for understanding knowledge-based economic development. J. Technol. Tran. 31, 175–188. https://doi.org/10.1007/s10961-005-5029-z.

Beyer, P., 2013. Developing socially responsible intellectual property licensing policies: non-exclusive licensing initiatives in the pharmaceutical sector. In: Research Handbook on Intellectual Property Licensing, pp. 227–256. https://doi.org/10.4337/9781781005989.00018.

Bican, P.M., Guderian, C.C., Ringbeck, A., 2017. Managing knowledge in open innovation processes: an intellectual property perspective. J. Knowl. Manag. 21, 1384–1405. https://doi.org/10.1108/JKM-11-2016-0509.

Bogers, M., Bekkers, R., Granstrand, O., 2012. Intellectual property and licensing strategies in open collaborative innovation. In: Open Innovation in Firms and Public Administrations: Technologies for Value Creation. IGI global, pp. 37–58.

Boldrin, M., Levine, D.K., 2008. Against Intellectual Monopoly, 1. Publ. Cambridge Univ. Press, New York, NY.

Calza, F., Parmentola, A., Tutore, I., 2017. Types of green innovations: ways of implementation in a non-green industry. Sustainability 9, 1301. https://doi.org/10.3390/su9081301.

Cayton, S., 2020. The "green patent paradox" and fair use: the intellectual property solution to fight climate change. Seattle Journal of Technology, Environmental & Innovation Law 11.

Chen, J.-Y., Dimitrov, S., 2017. Eco-innovation with opportunity of licensing and threat of imitation. J. Clean. Prod. 147, 306–318. https://doi.org/10.1016/j.jclepro.2017.01.052.

Chesbrough, H., 2006. Open Business Models: How to Thrive in the New Innovation Landscape. Harvard Business Press.

Chesbrough, H., Vanhaverbeke, W., West, J., 2014. New Frontiers in Open Innovation. OUP, Oxford.

Chung, J., Lorenz, A., Somaya, D., 2019. Dealing with intellectual property (IP) landmines: defensive measures to address the problem of IP access. Res. Pol. 48, 103828 https://doi.org/10.1016/j.respol.2019.103828.

Cockburn, I.M., MacGarvie, M.J., Müller, E., 2010. Patent thickets, licensing and innovative performance. Ind. Corp. Change 19, 899–925. https://doi.org/10.1093/icc/dtq035.
Consilvio, M., 2011. The role of patents in the international framework of clean technology transfer: a discussion of barriers and solutions. Intellectual Property Brief 3.
Contreras, J.L., 2015. Patent pledges: between the public domain and market exclusivity. Mich. St. L. Rev. 787.
Contreras, J.L., Hall, B.H., Helmers, C., 2019. Pledging Patents for the Public Good: Rise and Fall of the Eco-Patent Commons 40.
Correa, C.M., 2004. Ownership of knowledge: the role of patents in pharmaceutical R&D. Bull. World Health Organ. 82, 784–787. https://doi.org/10.1590/S0042-96862004001000015.
Crittenden, W.F., Crittenden, V.L., Pierpont, A., 2015. Trade secrets: managerial guidance for competitive advantage. Business Horizons, SPECIAL ISSUE: THE MAGIC OF SECRETS 58, 607–613. https://doi.org/10.1016/j.bushor.2015.06.004.
Delerue, H., Lejeune, A., 2011. Managerial secrecy and intellectual asset protection in SMEs: the role of institutional environment. J. Int. Manag. 17, 130–142. https://doi.org/10.1016/j.intman.2010.10.002.
Ehrnsperger, J.F., Tietze, F., 2019. IP pledges, open IP or patent pools? Developing taxonomies in the thicket of terminologies.
Eppinger, E., Tinnemann, P., 2014. Technology transfer of publicly funded research results from academia to industry: societal responsibilities?. In: Responsible Innovation 1. Springer, pp. 67–88.
Eppinger, E., Jain, A., Vimalnath, P., Gurtoo, A., Tietze, F., Hernandez Chea, R., 2021. Sustainability transitions in manufacturing: the role of intellectual property. Curr. Opin. Environ. Sustain. 49, 118–126. https://doi.org/10.1016/j.cosust.2021.03.018.
EREMA, 2019. EREMA Group Continues to Grow and Increases Turnover by 16 Percent. https://www.erema.com/en/erema_news/IDobj=2247, 15 06 2021.
European Commission, 2015. Directorate general for employment, social Affairs and inclusion., organisation for economic Co operation and development. In: Policy Brief on Scaling the Impact of Social Enterprises: Policies for Social Entrepreneurship. Publications Office, LU.
Ferreira, J.J.M., Fernandes, C.I., Ferreira, F.A.F., 2020. Technology transfer, climate change mitigation, and environmental patent impact on sustainability and economic growth: a comparison of European countries. Technol. Forecast. Soc. Change 150, 119770. https://doi.org/10.1016/j.techfore.2019.119770.
Fischer, T., Henkel, J., 2012. Patent trolls on markets for technology – an empirical analysis of NPEs' patent acquisitions. Res. Pol. 41, 1519–1533. https://doi.org/10.1016/j.respol.2012.05.002.
Fujii, H., Managi, S., 2016. Research and development strategy for environmental technology in Japan: a comparative study of the private and public sectors. Technol. Forecast. Soc. Change 112, 293–302. https://doi.org/10.1016/j.techfore.2016.02.012.
Gartner, W.B., 1985. A conceptual framework for describing the phenomenon of new venture creation. AMR (Adv. Magn. Reson.) 10, 696–706. https://doi.org/10.5465/amr.1985.4279094.
Geuna, A., Nesta, L.J.J., 2006. University patenting and its effects on academic research: the emerging European evidence. Research Policy, Property and the pursuit of knowledge. IPR issues affecting scientific research 35, 790–807. https://doi.org/10.1016/j.respol.2006.04.005.
Ghafele, 2012. Open Innovation for Sustainability: Lessons from the GreenXchange Experience.
Hall, B.H., Helmers, C., 2013. Innovation and diffusion of clean/green technology: can patent commons help? J. Environ. Econ. Manag. 66, 33–51. https://doi.org/10.1016/j.jeem.2012.12.008.
Han, J., 2017. Technology commercialization through sustainable knowledge sharing from university-industry collaborations, with a focus on patent propensity. Sustainability 9. https://doi.org/10.3390/su9101808.
Hannah, D.R., 2005. Should I keep a secret? The effects of trade secret protection procedures on employees' obligations to protect trade secrets. Organ. Sci. 16, 71–84. https://doi.org/10.1287/orsc.1040.0113.
Henkel, J., 2006. Selective revealing in open innovation processes: the case of embedded Linux. Res. Pol. 35, 953–969. https://doi.org/10.1016/j.respol.2006.04.010.
Henkel, J., Reitzig, M., 2008. Patent sharks and the sustainability of value destruction strategies. Proceedings 1–6. https://doi.org/10.5465/ambpp.2008.33653927, 2008.
Henkel, J., (neé Pangerl), Lernbecher, M, S., 2008. Defensive publishing - an empirical study. https://doi.org/10.2139/ssrn.981444.
Henry, C., Stiglitz, J.E., 2010. Intellectual property, dissemination of innovation and sustainable development. Global Policy 1, 237–251. https://doi.org/10.1111/j.1758-5899.2010.00048.x.
Henry, M., Bauwens, T., Hekkert, M., Kirchherr, J., 2020. A typology of circular start-ups: analysis of 128 circular business models. J. Clean. Prod. 245, 118528 https://doi.org/10.1016/j.jclepro.2019.118528.
Holgersson, M., Wallin, M.W., 2017. The patent management trichotomy: patenting, publishing, and secrecy. Manag. Decis. 55, 1087–1099. https://doi.org/10.1108/MD-03-2016-0172.
Holgersson, M., Granstrand, O., Bogers, M., 2018. The evolution of intellectual property strategy in innovation ecosystems: uncovering complementary and substitute appropriability regimes. Long. Range Plan. 51, 303–319. https://doi.org/10.1016/j.lrp.2017.08.007.
Hsieh, H.-F., Shannon, S.E., 2005. Three approaches to qualitative content analysis. Qual. Health Res. 15, 1277–1288. https://doi.org/10.1177/1049732305276687.
Huang, C.-Y., Yang, Y., Cheng, C.-C., 2017. The growth and welfare analysis of patent and monetary policies in a Schumpeterian economy. Int. Rev. Econ. Finance 52, 409–426. https://doi.org/10.1016/j.iref.2017.03.010.
Hughes, J., 1988. The philosophy of intellectual property. Geo. L. J. 287.
Jain, A., Gurtoo, A., 2021. Can the restrictive boundaries of intellectual property create a larger social impact? Curr. Sci. 120, 3.
Jain, A., Ogden, J., 1999. General practitioners' experiences of patients' complaints: qualitative study. BMJ 318, 1596–1599. https://doi.org/10.1136/bmj.318.7198.1596.
Jakobsen, S., Clausen, T.H., 2016. Innovating for a greener future: the direct and indirect effects of firms' environmental objectives on the innovation process. Journal of Cleaner Production, New approaches for transitions to low fossil carbon societies: promoting opportunities for effective development, diffusion and implementation of technologies, policies and strategies 128, 131–141. https://doi.org/10.1016/j.jclepro.2015.06.023.
Jardon, C.M., Dasilva, A., 2017. Intellectual capital and environmental concern in subsistence small businesses. Manag. Environ. Qual. Int. J. 28, 214–230. https://doi.org/10.1108/MEQ-05-2015-0085.
Kalanje, C.M., 2006. Role of Intellectual Property in Innovation and New Product Development. World Intellectual Property Organization.
Keskin, D., Diehl, J.C., Molenaar, N., 2013. Innovation process of new ventures driven by sustainability. Journal of Cleaner Production, Sustainable Innovation and Business Models 45, 50–60. https://doi.org/10.1016/j.jclepro.2012.05.012.
Kim, Y., Vonortas, N.S., 2006. Determinants of technology licensing: the case of licensors. Manag. Decis. Econ. 27, 235–249. https://doi.org/10.1002/mde.1249.
Kwon, O., 2020. A study on how startups approach sustainable development through intellectual property. Sustain. Dev. 28, 613–625. https://doi.org/10.1002/sd.2012.
Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A.C., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., Folke, C., Olsson, P., 2012. Transforming innovation for sustainability. Ecol. Soc. 17.
León, L.R., Bergquist, K., Wunsch-Vincent, S., Xu, N., Fushimi, K., 2017. Measuring Innovation in Energy Technologies: Green Patents as Captured by WIPO's IPC Green Inventory. WIPO.
Lewis, L., 2018. Evergreening through trade secrets as an impediment to green technology transfer to the developing world. Asper Rev. Int'l Bus. & Trade L. 18, 23.
Libaers, D., Hicks, D., Porter, A.L., 2016. A taxonomy of small firm technology commercialization. Ind. Corp. Change 25, 371–405. https://doi.org/10.1093/icc/dtq039.
Liddicoat, J., 2017. Standing on the edge – what type of "exclusive licensees" should be able to initiate patent infringement actions? IIC International Review of Intellectual Property and Competition Law 48, 626–651. https://doi.org/10.1007/s40319-017-0620-z.
Losacker, S., 2022. 'License to green': regional patent licensing networks and green technology diffusion in China. Technol. Forecast. Soc. Change 175, 121336. https://doi.org/10.1016/j.techfore.2021.121336.
Mann, R.J., 2004. Do patents facilitate financing in the software industry. Tex. Law Rev. 83, 961.
Matricano, D., 2020. Economic and social development generated by innovative startups: does heterogeneity persist across Italian macro-regions? Econ. Innovat. N. Technol. 1–18. https://doi.org/10.1080/10438599.2020.1823675, 0.
Mimura, C., 2009. Nuanced Management of IP Rights: Shaping Industry-University Relationships to Promote Social Impact. Social Science Research Network, Rochester, NY. SSRN Scholarly Paper No. ID 1434545).
Niezen, G., Eslambolchilar, P., Thimbleby, H., 2016. Open-source hardware for medical devices. BMJ Innovations 2. https://doi.org/10.1136/bmjinnov-2015-000080.
Oh, C., Matsuoka, S., 2016. Complementary approaches to discursive contestation on the effects of the IPR regime on technology transfer in the face of climate change. J. Clean. Prod. 128, 168–177. https://doi.org/10.1016/j.jclepro.2015.09.050.
Open Source Hardware Association, 2021. The state of open source hardware 2021. https://static1.squarespace.com/static/60d61d5e5321e9074a0e5080/t/60f5a80bb01550769d6371e5/1626712077449/stateofoshw-2021.pdf, 15 06 2021.
Organisation for Economic Co-operation and Development (OECD), 2009. Eco-innovation in Industry: Enabling Green Growth. OECD, Paris.
Oster, S.M., 1995. Exclusive licensing in a sequence of innovations. Int. J. Econ. Bus. 2, 185–198. https://doi.org/10.1080/758519307.
Pisano, G.P., Teece, D.J., 2007. How to capture value from innovation: shaping intellectual property and industry architecture. Calif. Manag. Rev. 50, 278–296. https://doi.org/10.2307/41166428.
Pitkethly, R.H., 2001. Intellectual property strategy in Japanese and UK companies: patent licensing decisions and learning opportunities. Res. Pol. 30, 425–442.
Purcell, W.M., Henriksen, H., Spengler, J.D., 2019. Universities as the engine of transformational sustainability toward delivering the sustainable development goals: "Living labs" for sustainability. Int. J. Sustain. High Educ. 20, 1343–1357. https://doi.org/10.1108/IJSHE-02-2019-0103.
Qi, G., Jia, Y., Zou, H., 2021. Is institutional pressure the mother of green innovation? Examining the moderating effect of absorptive capacity. J. Clean. Prod. 278, 123957 https://doi.org/10.1016/j.jclepro.2020.123957.
Rasmussen, E., Mosey, S., Wright, M., 2011. The evolution of entrepreneurial competencies: a longitudinal study of university spin-off venture emergence. J. Manag. Stud. 48, 1314–1345. https://doi.org/10.1111/j.1467-6486.2010.00995.x.
Reitzig, M., 2007. How executives can enhance IP strategy and performance. MIT Sloan Manag. Rev. 49, 37.
Roh, T., Lee, K., Yang, J.Y., 2021. How do intellectual property rights and government support drive a firm's green innovation? The mediating role of open innovation. J. Clean. Prod. 317 https://doi.org/10.1016/j.jclepro.2021.128422. N.PAG-N.PAG.
Rourke, L., Anderson, T., 2004. Validity in quantitative content analysis. ETR&D 52, 5–18. https://doi.org/10.1007/BF02504769.

Schiederig, T., Tietze, F., Herstatt, C., 2012. Green innovation in technology and innovation management – an exploratory literature review. R D Manag. 42, 180–192. https://doi.org/10.1111/j.1467-9310.2011.00672.x.

Schmitz, P.W., 2007. Exclusive versus non-exclusive licensing strategies and moral hazard. Econ. Lett. 97, 208–214. https://doi.org/10.1016/j.econlet.2007.03.021.

Shane, S., Cable, D., 2002. Network ties, reputation, and the financing of new ventures. Manag. Sci. 48, 364–381. https://doi.org/10.1287/mnsc.48.3.364.7731.

Shapiro, C., 2000. Navigating the patent thicket: cross licenses, patent pools, and standard setting. Innovat. Pol. Econ. 1, 119–150.

Shelton, R.D., Leydesdorff, L., 2012. Publish or patent: bibliometric evidence for empirical trade-offs in national funding strategies. J. Am. Soc. Inf. Sci. Technol. 63, 498–511. https://doi.org/10.1002/asi.21677.

Söderholm, P., 2020. The green economy transition: the challenges of technological change for sustainability. Sustainable Earth 3, 6. https://doi.org/10.1186/s42055-020-00029-y.

Stefan, I., Bengtsson, L., 2017. Unravelling appropriability mechanisms and openness depth effects on firm performance across stages in the innovation process. Technol. Forecast. Soc. Change 120, 252–260. https://doi.org/10.1016/j.techfore.2017.03.014.

Stefan, A., Paul, L., 2008. Does it pay to Be green? A systematic overview. AMP 22, 45–62. https://doi.org/10.5465/amp.2008.35590353.

Sternkopf, J., Tietze, F., Eppinger, E., Vimalnath, P., 2016. Open IP Strategies for Enabling Sustainability Transitions (Working Paper). Centre for Technology Management, Institute for Manufacturing. https://doi.org/10.17863/CAM.7143.

Swanson, T., Goeschl, T., 2014. The Distributive Impact of Intellectual Property Regimes: A Report from the "Natural Experiment" of the Green Revolution1. https://doi.org/10.1093/acprof:oso/9780199660759.003.0009.

Tang, A., Tietze, F., 2021. Intellectual Property Strategy Trajectory: A New Visualisation Approach (Working Paper). https://doi.org/10.17863/CAM.75500.

Teece, D.J., 1986. Profiting from technological innovation: implications for integration, collaboration, licensing and public policy. Res. Pol. 15, 285–305. https://doi.org/10.1016/0048-7333(86)90027-2.

Thomas, D.R., 2003. For qualitative data analysis. UNEP report – "Patents and clean energy: bridging the gap between evidence and policy. Manag. Environ. Qual. Int. J. 22 https://doi.org/10.1108/meq.2011.08322bab.004, 2011.

Urbaniec, M., Tomala, J., Martinez, S., 2021. Measurements and trends in technological eco-innovation: evidence from environment-related patents. Resources 10, 68. https://doi.org/10.3390/resources10070068.

Van Etten, D.W., 2007. Everyone in the patent pool: U.S. Philips corp. v. International trade commission. Berk. Technol. Law J. 22, 241–258.

Vimalnath, P., Tietze, F., Eppinger, E., Sternkopf, J., 2020. Closed, semi-open, or fully-open? Towards an intellectual property strategy typology. Proceedings 2020, 22070. https://doi.org/10.5465/AMBPP.2020.22070abstract.

Vimalnath, P., Gurgula, O., Scott-Ram, N., Bountra, C., Lee, W.H., 2021. Affordable medicines and innovation: consequences and lessons from countries with different patentability standards. Bio-Science Law Review 18, 119–128.

Winston, E.I., 2006. Why sell what you can license - contracting around statutory protection of intellectual property. George Mason. Law Rev. 14, 93.

Ziegler, N., Gassmann, O., Friesike, S., 2014. Why do firms give away their patents for free? World Patent Inf. 37, 19–25.