Centre for Technology Management working paper series

ISSN 2058-8887

No. 2020/01

January 2020

IP Strategies for Green Innovations - An Analysis of European Inventor Awards

https://doi:10.17863/CAM.48823

Pratheeba Vimalnath (IfM, University of Cambridge) *
Frank Tietze (IfM, University of Cambridge)
Akriti Jain (Centre for Society and Policy, Indian Institute of Science)
Viola Prifti (University of Applied Science, HTW-Berlin)

* Please contact the corresponding author for feedback:
pv302@cam.ac.uk

UNIVERSITY OF CAMBRIDGE

IfM Centre for Technology Management

IP Strategies for Green Innovations - An Analysis of European Inventor Awards

Pratheeba Vimalnath[1], Frank Tietze[1], Akriti Jain[2], Viola Prifti[3]

[1]Institute for Manufacturing, University of Cambridge, Cambridge, United Kingdom
[2]Centre for Society and Policy, Indian Institute of Science, Bengaluru, India
[3]University of Applied Science, HTW-Berlin, Berlin, Germany

Abstract

To drive sustainability transitions on a global scale for a carbon neutral future, green innovations are needed. In this study, we are keen to understand the role of intellectual property (IP) and particularly, its usage by firms innovating for a sustainable future. Unfortunately, little is known about how IP impacts sustainability transitions. To contribute to a better understanding, we chose to investigate IP usage by award - winning green innovators. We study the winners of the European Inventor Award, a highly prestigious international prize, awarded annually by the European Patent Office since 2006. Among all 210 awardees, we identified 52 winners that we classified as green innovators. Our analysis shows that closed and semi-open IP, particularly non-exclusive licensing, are the preferred IP strategies for green innovations. The IP strategy preferences seem to vary across technology domains. These findings are discussed along with their implications.

Keywords: intellectual property strategy, patent, licensing, collaboration, green innovation, circular economy, sustainability, European inventor award

1. Introduction

This study is part of a wider project called IPACST[1] during which we are keen to better understand the role of intellectual property (IP) and particularly its usage by innovators for a sustainable future. Developing, adopting, and widely diffusing green innovations is vital to combat climate change and foster sustainable future.

In this paper, we present an analysis of how innovators have used IP, particularly patents for a set of highly successful innovations with environmental impact, that were featured in European Inventor Awards (EIA). Amongst these are technologies, which have enabled massive energy savings in industrial applications, much more efficient wastewater treatment and purification systems and large scale plastic recycling, to name only a few.

The European Inventor Award (EIA) is a widely recognized and highly prestigious prize awarded by the European Patent Office (EPO). The EIA are presented every year by the EPO

[1] www.ip4sustainability.org

to inventors in different categories to celebrate innovation across industries and technologies. A common element among the EIA related patents is the generation of some form of impact in the green sector. The EPO started the EIA initiative in 2006 and continues every year to celebrate inventors behind breakthrough inventions. According to the EPO, "the award gives inventors the recognition they deserve. And, like every competition, it acts as an incentive for other potential winners. It helps to protect ideas and encourage innovation." The awards are given under five categories namely industry (large European firms), small and medium enterprises (SMEs), research, non-EPO countries and life time achievement. In each of the categories, members of the public can nominate inventors for the award. An EPO international expert jury evaluates the nominated innovations "not only on their technological originality but also on their economic and social impact". Every year, for each category, the EPO lists two finalists and one winner on its website[2]. As of September 2019, a total of 201 entries including finalists and award winners in different categories were listed in the EPO website for the period from 2006 to 2019. We identified 52 out of the 201 entries as green innovations and qualitatively analyzed them to provide evidence based insights on the preferred IP strategies for successful green innovations.

The body of literature discussing role of IP for sustainability is limited. Literature on the strategic and managerial aspects of IP provides evidence that companies can strategically use their IP to bring structural changes in the industry and the economy (Pisano & Teece, 2007; Lesser, 1998; Gambardella & McGahan, 2010), but with hardly any focus on the aspect of sustainability. A company can bring structural change by reengineering the appropriability regimes it operates in, i.e., strengthening or weakening to its advantage environmental factors, excluding firm and market structure, that govern an innovator's ability to capture the profits generated by an innovation (Pisano & Teece, 2007; Teece, 1986). At the industry level, IP rights are shown to "affect entry, make vertical integration in downstream industries more or less necessary, and create financial resources encouraging downstream mergers and acquisitions", and create significant structural impact as evidenced for example in the agricultural biotechnology industry (Lesser, 1998). It is also noted that business model innovation centred around development and licensing of general purpose technologies to downstream players has potential to alter industry structures and innovation capabilities (Gambardella & McGahan, 2010). In the context of sustainability, however, whether IP can facilitate or hinder green innovations remains largely unexplored.

Companies take strategic decisions to either share their inventions and IP rights by royalty free licensing; or restrict access and use by others through IP protection and non-sharing (Chesbrough et al., 2014; Sternkopf et al., 2016). In between these extremities, there exist other forms of IP sharing like selective licensing, patent pools, and patent pledges with restrictive clauses (Sternkopf et al., 2016). These strategies can be broadly classified as closed, semi-open or fully-open IP strategies (Vimalnath et al., 2019). Which of these IP strategies will facilitate or hinder sustainable business model is less understood. It could be the case that all these IP strategies become relevant but under different settings. Theoretical and empirical insights along

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

these lines are lacking. The paper attempts to address this gap by providing empirically-based insights on the IP strategies used by sustainability focused inventions, especially green inventions (Schiederig et al., 2012). We present a descriptive analysis of the EIA winners and finalists, and identify different IP strategies used in the context of green innovations. There are no systematic studies that provide insights about whether a particular IP strategy becomes more or less relevant for green innovations.

We conduct an exploratory qualitative data analysis using a set of 52 green innovations, a sub-sample from all 201 EIA entries, to understand the IP strategies used for successful green innovations. From this sub-sample we provide examples of cases illustrating different IP strategies.

The paper is structured as follows. Section 2 provides a review of literature on different IP strategies and related initiatives. Section 3 describes our methodology. Section 4 presents the results with examples of cases employing different IP strategies and differences across technology domains. Section 5 discusses the results followed by conclusions in section 6 with contributions, implications and future research.

2. Literature review

The literature review conducted for this paper analyses the use of intellectual property (IP) and its impact by companies operating in the green sector, with a particular focus on patent rights. More than 80 papers were identified and thoroughly read through a combination of a systematic and a reference search in the period June – December 2019. For the systematic search, the search terms were “patent sustainability”, “IPR sustainability”, "Intellectual property eco", "intellectual property climate change", "intellectual property green", "patent sustain*" on the following databases: EconPapers, Web of Science, Science Direct, Research Gate, and Google Scholar. The papers combine theoretical and empirical studies. After reading the abstracts and conclusions of all papers, we selected about 60 papers for a detailed literature analysis. In absence of precise definitions of terms such as “green technology”, “climate change”, and “sustainability” as well as a lack of understanding of the link between these terms, IP and sustainability impact, we examined patent strategies in several industrial sectors.

Before delving into the literature review, it is important to explain that IP is an instrument that incentivises companies to invest in R&D by allowing them to capture value from innovation during a monopolistic period and, as such, it should align with their interest of profit-making. Based on business objectives, companies may adopt different IP strategies that can fall under three main categories: closed (when IP is not licensed); semi-open (when IP is licensed); or fully-open (when the use of IP falls into the public domain) (Vimalnath et al., 2019). It is to be noted that the use of the term “open” is adopted differently by companies and policymakers (Bonvoisin et al., 2017; de Beer, 2015) to indicate different degrees of openness. To avoid confusion, we use the term “open” an umbrella term for different types of openness.

It can be envisaged that most companies would make use of all these strategies to bring their innovations to the marketplace. Indeed, doing business in today's knowledge economy requires interaction. In terms of patent strategy, this means that all firms should capture an adequate value in order to be incentivized to collaborate. Defining the "adequate value" is certainly challenging due to market uncertainties. Economic theory suggests that strong patent protection helps firms recoup R&D costs and thus it provides incentives to innovate (Machlup, 1958, pp.38, 59-60; Machlup and Penrose, 1950, pp. 1-29). Empirical evidence also suggests that effective patent protection is a means to promote technology transfer toward developing countries when foreign technology providers face the threat of imitation by local competitors (Dechezleprêtre et al., 2011). Although some authors have argued that weak IP protection is necessary for building up local capacities (Kumar, 2002; Freeman, 1995), legal mechanisms that weaken IP rights might lead the industry to reduce investments in research and development (Gervais, 2012; Drahos, 2011, p. 1; Correa, 2007; Abbott, 2009). Indeed, it has been shown that weak patent protection has a strong and negative influence on the international diffusion of patented knowledge for low-carbon technologies (Dechezleprêtre, 2012). As a consequence, we can assume that a closed patent strategy plays a similar role because it allows firms to reap more profit.

However, in a real-world scenario licensing patent rights can be both a necessity (to develop and/or bring to the market an innovation) and a tool to reap financial benefits. There are different ways to license patent rights and collaborate, such as patent pools, patent commons, open licensing agreements, and non-assertion pledges (WIPO, 2009, p. 4). Patent pools or cross-licenses are often a strategy used by firms when they need access to a protected technology or simply avoid patent litigation (Choi, 2003). This type of strategy may create a win-win situation for firms despite the risk of anticompetitive practices (WIPO, 2014). While the social benefits of patent pools are debatable (Merges and Mattioli, 2016), it has been argued that patent pools may in theory be viable options to allow competitors to contribute to the energy sector while maintaining the benefits of strong patent laws (Strobel, 2013, p. 526). One dilemma, indeed, that patentees may face when deciding to cross-license or share their IP in a patent pool is related to the incentive to innovate and recoup their R&D costs while making their IP available to competitors. We will explain in the next paragraphs that firms did not share valuable IP in the Eco-Patent Commons, an international collaboration between firms that pledged some of their patents in the green sector.

Some firms also rely on a fully open IP strategy under certain conditions. This is often the case for open-source software with numerous examples, including the Linux operating system, Facebook Open Compute, and important open source projects by multinationals such as IBM, Bosch, etc.. These businesses see "competitive advantage in giving away code without restricting access to it, so others can develop it further and add more value to the collective" (Jeyakodi and Ros, 2019, p. 61). This is not only because the open source community can produce and enhance the software more and better than a single proprietor, but it can also share the costs. The costs for developing software are quiet low compared to other industries (Strobel, 2013), which may make cooperation more feasible. However, even for open source software, companies protect commercializable knowledge as stated on the "Bosch Eclipse" project website[3]. This can occur when technology developed through open source is embedded into tangible products. Although some companies claim to have put their patents on the public domain (e.g. Tesla), based on neoclassical economic theory it is challenging to envisage an open source patent strategy for hardware while maintaining competitive advantage. A study on this point has indeed argued that an open IP strategy for hardware creates financial issues for incentivizing innovations (Beldiman, 2018).

The same arguments are valid also in the context of green innovation. It has been suggested that relaxing IPRs will discourage innovation by "reducing potential financial rewards, particularly with respect to very dynamic markets like the global renewable energy technology market at a time when a growing number of countries (including developing nations) are implementing various initiatives to facilitate and encourage renewable energy research and development" (Percival and Miller, 2011, p. 20). Empirical evidence shows that the impact of strict IP rights on technology transfer is large with respect to climate change mitigation (Dechezleprêtre, 2012). Strong patent protection can be necessary also in developing countries where companies are reluctant to deploy cutting-edge technologies (Ockwell et al., 2010; Harvey, 2003).

We expect firms to patent in the clean technology sector. It has been found that a "firm's propensity to patent increases in industries in which reverse engineering is relatively easy" (Han, 2017, p. 4). This is the case of clean technologies. Indeed, after the adoption of the Kyoto Protocol, patents on clean technologies rose dramatically. It appears, thus, that innovation in clean technology is driven through the patent system (Consilvio, 2012, p. 8). Currently, patenting of clean energy technologies is dominated by OECD countries led by Japan, United States, Germany, the Republic of Korea, France, and the United Kingdom (Karachalios et al., 2010). Patents by China are also on the rise but China argues that patents are an obstacle to clean technology transfer due to limited access to patented clean technologies (Consilvio, 2012, p. 12). This can be counter argued by the fact that patent filings in clean technology sectors are almost non-existent in the least developed countries (Copenhagen Economics, 2009). Another study has also found that IP barriers for clean energy technologies are insignificant for developing countries (Barton, 2007). Currently, there is hardly any evidence on the blocking effects of patents on the circular economy or green innovations.

This may be due to the fact that companies collaborate through sharing their IP rights. Sharing rights through licensing or/and collaborative mechanisms promotes R&D and avoids duplication efforts (Krattiger and Kowalski 2007, p. 138; Van Overwalle et al. 2006, pp. 143-144) by affecting technology transfer. The effects of collaboration depend on the use of exclusive rights in technology transfer (WIPO, 2008). A major study has found that in the context of the clean energy technologies, actors prefer collaborative R&D mechanisms, patent out-licensing and joint ventures over patent pooling, cross-licensing, and technology and patent in-licensing (Karachalios et al., 2010). In contrast to academic institutions, public entities and private companies are more prone to enter collaboration mechanisms. Among private companies, multinationals are more active in sharing IP. Private firms appear to use

[3] https://iot.eclipse.org/case-studies/bosch-leadership-in-eclipse-iot/

collaborative R&D more frequently compared to any kind of IP mechanism (Karachalios et al., 2010, pp. 56-57). With respect to IP-sharing developing countries, the same survey found that there is a high willingness to out-license to developing countries and make the terms of licenses more flexible. The findings, however, show that there is little out-licensing activity to developing countries. To increase out-licensing, it was suggested to improve market conditions in developing countries.

Market conditions and other factors beyond IP-sharing may be one reason for the non-success of international collaboration mechanisms in the green sector. One large unsuccessful effort for transferring technology on a royalty free licensing approach was the Eco-Patent Commons. Its failure may be a consequence of a loss of competitive advantage for firms that allow any third party to make use of their patents while covering the costs of maintaining IP rights. An analysis of the Eco-Patent Commons initiative shows that "most of the patents pledged were neither used nor did they represent an essential source of business advantage to their owners" (Awad, 2015, p. 6). GreenXchange, another initiative that provided for different degrees of openness, from semi-open to fully open, has also failed. Research and evidence in the green sector show that lack of serious intention to collaborate and share innovation with other partners leads to failure of sharing patent rights. Although many claim to pledge patents, patents in the green sector are not fully in the public domain and free to be used by interested parties (Awad, 2015). We will examine this issue in the subsequent sections.

a) Closed patent strategies

We are not aware of any paper or case study which demonstrates that companies do not license any of their patents on clean technology. There are, however, many cases that show that companies refuse to license patents on particular technologies. These cases are usually made known through legal disputes. A major case was that involving General Electrics (GE) and Mitsubishi on large wind turbines (General Electrics vs Mitsubishi, 2014). The patents held by GE covered core technologies for wind power generation from wind turbines. The patented wind turbines were imported in Texas by Mitsubishi. GE filed a lawsuit against Mitsubishi for patent infringement. The case involved substantial resources and lasted several years with one of the claimed patents expiring during the controversy. The decision was in favour of GE. In this particular case, it has been argued that the "implementation of wind power has been restricted because of the exclusion of a major player like Mitsubishi from the U.S. market." Restricted competition leads to increased prices and a slowdown of diffusion of innovations (Strobel, 2013, p. 520). There have been other legal controversies on green technologies that have confirmed patentee's rights on infringed patented technologies. It is, however, premature to conclude that a closed patent strategy will impede innovation. This depends on the market competition structure and the particular sector. Without specific studies for specific sectors, it is not possible to establish a causal relationship between a closed patent strategy and innovation impact. We presume that every company on the market adopts a closed IP (not patent) strategy to an extent. For example, trade secrets are common for those inventions which can be unlikely copied by competitors and thus can be easily kept secret to provide competitive advantage.

b) Semi-open patent strategy: Licensing and collaboration mechanisms

A semi-open patent strategy or differently called "collaboration mechanism" can have different forms such as licensing, patent commons, patent pools, etc. (Taubman, 2009).
1. Licensing

Licensing is an essential part of promoting innovation because it allows to transfer knowledge and thus implement technological innovations. But licensing itself is not sufficient to enable innovation. Licensing of a patented technology does not necessarily equate to a transfer of technology. "Unlike a pharmaceutical patent, where disclosure of a chemical formula may be sufficient to produce the product, a clean technology patent may not disclose enough information to actually commercialize the technology. Trade secrets or technical know-how might be required and would be beyond the disclosure of the patent." (Consilvio, 2012, pp. 12-13). A good example in the literature is that of a solar photovoltaic (PV) cell which can be protected by multiple patents and trade secrets:

> "The particular compositions of the layers of a p-n junction might be patented, but the method of obtaining the desired precision engineering of those layers might be a trade secret. Without the ability to precisely produce those layers, the true efficiency gain of the cell might never be realized. Therefore, a compulsory license may be insufficient for actual transfer of the clean technology, since it would only disclose part of the technology. Additional components, perhaps covered by other patents and possibly owned by other companies, may be necessary for implementation of the PV cell" (Consilvio, 2012, p. 13).

Another study on the wind power and photovoltaic industries in China argues that licenses are important vehicles for technology transfer but there are other factors (Zhou et al., 2018) that may have larger influence such as tacit flows of knowledge. Licensing, however, remains a tool for businesses to share IP and impact the sector. The type of impact will depend on licensing terms and conditions in addition to external factors, such as market structure.

2. Collaboration mechanisms: GreenXchange

Firms collaborate when they have shared interests. Numerous initiatives can be envisaged in the sector, but this section will focus on the semi-open model adopted by GreenXchange. GreenXchange was an initiative established in 2010 by Nike together with Creative Commons and Best Buy with the intent to share IP for green product design, packaging, manufacturing, and other uses in order to increase access to sustainable innovations. The benefits of GreenXchange for sharing green innovations were largely discussed both in the sustainability (Makower, 2009) and the IP community (Ghafele and O'Brien, 2012). The sharing model of GreenXchange provided for three different types of licensing: a standard option, a standard PLUS option, and a research non-exempt option. The standard option allows a royalty-free license under which users can utilise IP knowledge for free as they wish. No system to track users and IP impact was foreseen. The standard PLUS option, similarly to patent licenses, provides for payment in exchange of use of disclosed IP knowledge and contractual restrictions. The research non-exempt option draws upon the existing research exemption as commonly adopted by most jurisdictions to permit non-commercial research. But differently from patent law provisions, the GreenXchange research non-exempt option allows only patenting of potential improvements and modifications for non-commercial use. By excluding commercial use, this type of license creates a safe environment for businesses that make their IP available against possible uses of shared IP by competitors.

Despite good intentions to accelerate a transition to sustainability, the implementation of these licensing models encountered several challenges such as the current model on IP protection and management, the fact that patents are not an essential part of "open innovation-inspired attempts to promote sustainability business models", and lack of resources for realizing the project at international level (Ghafele and O'Brien, 2012, pp. 4 - 7). Nevertheless, GreenXchange is seen as an important initiative to pave the way forward for sustainability diffusion. The three main lessons are believed to rely on the benefits of education on open innovation-inspired IP exchanges, different ways to promote innovation through IP licensing (e.g. tax credit and/or public support) and the importance of connecting people (Ghafele and O'Brien, 2012, pp. 7 - 8).

c) Fully open patent strategy

Companies that adopt a fully open patent strategy put their patents in the public domain either by ceasing payment of patent maintenance fees or by pledging their patents. A general definition of patent pledge may be the following:

"A patent pledge is a publicly announced intervention by patent owning entities ('pledgers') to out-license active patents to the restricted or unrestricted public free from or bound to certain conditions for a reasonable or no monetary compensation using standardized written or social contracts." (Ehrnsperger and Tietze, 2019, p. 1).

Pledges have often been made in areas such as open source software (IBM, Sun, Google and Red Hat), electric vehicles (Tesla, Toyota), and biotechnology (Monsanto's pledge on patents covering genetically modified seeds against inadvertent infringement) (Contreras, 2015; Reynolds, Contreras and Sarnoff, 2017). To be coherent with the aim of this paper, we will focus on patent pledges that may impact the green sector.

1. Tesla's pledge

Tesla's pledge is certainly the most known and discussed both by the media and academic community. The famous phrase "All our patent are belong to you" in Elon Musk's post (Musk, 2014) leads to believe that Tesla has opened up its patents to the public. A superficial reading of the post certainly may convince some that Tesla was moved by altruistic reasons to open up its patent portfolio for the benefit of the electric car sector and consequently positively impact climate change. Whereas the effect of the production of electric cars on climate change remains controversial, it urges to clarify that Tesla is a company with business objectives. A closer look at Tesla's patent pledge helps us realize that the pledge is a smart lawyering technique.

Although the text of the pledge explains that no lawsuits will be initiated "against any party for infringing a Tesla Patent through activity relating to electric vehicles or related equipment for so long as such party is acting in good faith", the legal community has raised several concerns for those companies wishing to use Tesla's patents. These concerns mainly stem from the definition of "good faith" in the pledge. Companies need to give up any action against Tesla for IP infringement (to be noted that IP covers other types of IP rights in addition to patents). This may lead to the consequence that every company that uses pledged patents cannot bring lawsuits against Tesla if Tesla infringes their IP rights. Moreover, companies need to pledge their patents not only against Tesla, but against any company in the global market. This makes it very difficult to establish a competitive advantage. The pledge also requires that companies have no financial stakes in any challenge against Tesla's patents. It is not clear what "financial stake" may mean; the lack of clarity may help Tesla advance any claim.

Another concern regards the definition of "knock off". Although the pledge provides an example, it is not clear where the limits for copying or imitating Tesla's products are set (Collura, 2019). It is also worth noting that although Tesla's patent filings have risen in recent years, the most important patents in the electric and automotive sector are not held by Tesla but by Ford, Toyota, Denso, Bosch, etc. (Diakun, 2019). Indeed, several authors have argued that Tesla's pledge was a smart move to grow its market (Hill, 2016; Roberts, 2014). It would be interesting to know whether Tesla's patents are being used in the sector and the effect of the pledge on opening up the sector. What we know for certain is that Tesla struggled raising capital after the pledge (Diakun, 2019).

2. Toyota's pledge

A patent pledge that appears to be more realistic and feasible for impacting the automotive sector is made by Toyota. Toyota has pledged its patents several times and in 2015, it made 5,680 patents related to fuel cell drive systems available on a royalty-free basis until the end of 2030. The willingness of Toyota to make a change in the sector can be observed in the technical support to other manufacturers developing and selling electrified vehicles when they use Toyota's products (Ellis, 2019). The support is provided upon payment of a fee, but it is an important element to show positive action for transferring technology and impacting the sector.

3. Eco-Patent Commons

The paragraph on licensing suggests that patent commons are a form of IP collaboration between firms. While this is true, we propose to describe the Eco-Patent Commons as a form of fully-open IP strategy because participating companies pledged their patents in the green sector. The initiative was established in 2008 by some of the world's biggest companies, such as IBM, Nokia, Sony, DuPont, Bosch, and Pitney Bowes with the goal to offer royalty free access to patents covering 94 green inventions. As stated on the Eco-Patent Commons' website, its mission is to "manage a collection of patents pledged for unencumbered use by companies and IP rights holders around the world to make it easier and faster to innovate and implement industrial processes that improve and protect the global environment". Although this initiative received media coverage, academic attention, and was praised in the IP community (Bowman, 2009), it was discontinued in 2016 due to its inefficiency.

The main reasons for putting an end to the Eco-Patent Commons seem to be related to the absence of a system to track usage of patents, the lack of a technology transfer system, no user-friendly website, and a shift in corporate priorities (Contreras et al., 2018, pp. 8-9). The lack of usage tracking did not allow to assess the use and impact of the initiative. More importantly, it was not possible to effectively implement innovations based only on patent disclosure. As shown in some studies, technical assistance and know-how are far more essential for environmental technologies than they are for software or pharmaceuticals (Barton et al. 2002; McManis and Contreras, 2014). Contreras et al (2018) explain that there were no obvious benefits for parties involved beyond reputational enhancement. Perhaps a major flaw of this mechanism is to be identified in the fact that patent ownership maintained by involved parties comes with costs, which are not shared with competitors if patents are made available royalty-free.

Contrary to a quantitative study in 2013 which concluded on the "helpfulness" of patent commons based on the informational value of donated patents and their potential to drive green innovation (Hall and Helmers, 2013), the updated qualitative study following the termination of the Eco-Patents involving the same authors found that the initiative did not have any effect on the diffusion of green technologies (Contreras et al., 2018, p. 1). As already mentioned above, Awad (2015) found that "most of the patents pledged were neither used nor did they represent an essential source of business advantage to their owners" (p. 6).

What is interesting to notice about the Eco-Patents is the fact that the main drive to join the initiative came from the "environmental and social responsibility" unit "with express goals directed at environmental sustainability", with the legal department acting as a consultant subsequently for identifying suitable patents for contribution (Contreras et al., 2018, p. 6). This finding seems to contradict previous literature on the relevance of the public perception of a business (Contreras, 2015, p. 591; Consilvio, 2012, p. 13; Van Hoorebeek and Onzivu, 2010, p. 18) for guiding sustainability initiatives. However, the qualitative study conducted by Contreras et al. also confirmed the positive public perception associated with the Eco-Patent Commons.

d) Other forms of collaboration: WIPO Green

It appears that international collaboration mechanisms that adopt both a semi-open and a full open patent model have been unsuccessful. An attempt to incentivize collaboration mechanisms in the green sector is being brought forward by the World Intellectual Property Organization (WIPO) through an online platform called "WIPO Green". WIPO Green is a public-private partnership established in 2013 by the WIPO that offers an online platform for exchanging technology that addresses climate change. The ultimate aim is to promote and diffuse sustainable technologies independently of their patentability. Patents are not a requirement for making the green technology on the platform. All technologies at all stages of development can be made available. When users share their patented technologies, these technologies are available for license, collaboration, joint venture and sale. It should be noted that technologies remain the property of the right holder and the type of collaboration is to be decided privately among parties. As stated in the "Frequently asked questions" of the WIPO Green website, as of May 2019, more than 3600 technologies and needs from circa 1200 users in 120 countries are part of the platform. There is no enforcement mechanism; thus the contribution remains entirely voluntary.

We have no information on the impact of WIPO Green. The literature review also does not provide relevant information for understanding the impact of different patent strategies on sustainability. There is no definitive answer unless the study focuses on a specific sector in a particular period of time. Moreover, the perception of impact may differ in different papers because of different variables. Studies have shown that impact of IP strategies depends on robust legal mechanisms, domestic institutions, allocation of investments, resources, infrastructure and conditions underpinning technology transfer in general (Burleson 2009; Ghafele 2015; De Koninck and Sagar, 2014; Consilvio 2012, Gechlik 2009; Hasper 2009; Maskus 2009). The following section is an attempt to understand the different types of patent strategies and their impact adopted by companies participating in the EPO Awards.

3. Methodology

For this exploratory study, we analyse qualitative data of about 52 green inventions from European Inventor Awards (EIA) following a general inductive approach (Thomas, 2003) suitable for qualitative data analysis. According to Thomas (2003), the inductive approach allows "research findings to emerge from the frequent, dominant or significant themes inherent in raw data, without the restraints imposed by structured methodologies." (p. 2).

Data source: For the exploratory analysis, we use secondary qualitative data from 52 green inventions recognized by the EPO for their "exceptional contributions to the social development, technological progress and economic growth", through its annual EIA. We find the EIA data relevant to this study because the EIA case descriptions provide details about how inventors have strategically used their IP, primarily patents but also other IP like trademarks, trade-secrets and know-how across all stages of the innovation process, namely research, development, market entry (commercialization), diffusion and impact. Further, since the awardees are the original inventors themselves, we consider the information provided by the EIA, which also includes interview transcripts from the inventors[4], as credible and trustworthy. Such a rich source of information is critical to derive insights on the IP strategies that have been tried, tested and shown to be successful in the context of green innovation.

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

Sample and unit of analysis: Since the inception of EIA in 2006 and until 2019, the EPO has listed a total of 201 entries including finalists and award winners. Out of those 201 cases, only 29 were classed as green technologies by the EPO, a sector classification introduced by the EPO itself in 2018. The inventions with green impact awarded prior to 2018 were not classified separately as green technologies. Therefore, we manually read through all the cases to identify those with green (i.e., ecological) impact (Schiederig et al., 2012) but not classified as green by the EPO. We followed the OECD's definition of 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), to classify green innovations. In addition to the 29 inventions classified as green technologies by the EPO, we identified additional 23 cases as green innovations leading to a total of 52 cases which constitute the sample for this analysis.

The awards are given in five categories, namely industry (large European firms), small and medium enterprises (SMEs), research, non-EPO countries and life time achievement for selected inventors. The categories are based on patent ownership irrespective of the originating place of the invention. This means, for example, that if the category is an SME, the patent on the invention is owned by that SME, but the invention could have also originated from a university. We, therefore, distinguish between the awardee type and the invention originator type. To maintain consistency in the analysis and in line with the purpose of our study to understand IP strategies for green inventions, we use award-winning inventions as the unit of analysis.

Data analysis: We performed a content analysis of qualitative data using MaxQda software to code the case descriptions provided on the EIA website for the selected sample of 52 cases. Broadly, the approach for content analysis can be of three types namely conventional, direct or summative content analysis depending on the "coding schemes, origins of codes, and threats to trustworthiness" (Hsieh & Shannon, 2005, p. 1277). We adopt directed content analysis approach and use the IP strategies categories identified from the IP literature as the starting point for coding the EIA data. The case descriptions in the EIA website provided details about the original invention, type of organization that developed the invention, the sector, award category, company name, case description and snippets from interviews with the inventors. From the case description, we were able to deduce insights about the innovation process (i.e., research and development, market entry, diffusion and impact) and related barriers, following the conventional content analysis approach (Hsieh & Shannon, 2005). This iterative hybrid method of generating coding based on literature as well as case description is common among the qualitative content analysis researchers (Rourke & Anderson, 2004). The qualitative secondary data from the EIA website was coded and cross-verified by a total of three experts, following the method used by Jain & Ogden (1999). First, the case texts were read carefully to understand the kind of information available within the details provided by the EIA website. After consolidation of the relevant codes and consensus among the experts, a coding frame was developed and the case descriptions coded. Every time a new code emerged, the coding frame was revised and the case descriptions were reread according to the new structure. After three rounds of revisions, the final set of coding frame included 11 different parent codes grouped under five categories. The code categories, parent codes and sub-codes are described in Table 1.

Table 1: Coding frame for studying patent strategies for green innovations

Code category	Parent code	Sub-code
General	Technology sector	Environment management, biodiversity, energy, building and transport, water, material/plastic/packaging, others
	Awardee category	Large firm, SME, academia/research institution, individual
Research and development	Invention originator	Individual, university/research institution, industry (SME, large, start-up)
	Development barriers	Technological barriers, economic barriers, others
IP strategy	IP generation	In-house, collaboration (academia-industry/ industry- industry/ individual-industry/ individual-individual collaboration)
	Motives for patenting	Protection from imitators, funding and investment, incentivizing innovation, recognition.
	Patent sharing strategy	Closed IP strategy/no sharing, closed IP strategy/patent sale, semi-open IP strategy/licensing, semi-open IP strategy/ collaboration or partnership with unknown IP sharing strategy, fully-open IP strategy/free access to IP, not available
	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)
Market entry	Market entry barriers	Technical challenges (e.g. lack of supporting technologies), financial challenges (high cost)
	Market entry strategy	Start-ups, own commercialization by the inventing organization, licensing to existing players, collaboration or partnership,
Diffusion	Diffusion barriers	Difficulty in changing user behaviour
	Diffusion strategy	Licensing to existing players, own commercialization by the inventing organization
Impact	Environmental	CO_2 and other greenhouse gas (GHG) emission reduction, efficiency, 3R (reduce, reuse and recycle)
	Social	Employment, public health, awareness and community development
	Economic	Production capacity, market spread, revenue, cost reduction/saving

Closed IP Strategy/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 strategy.

Closed IP Strategy/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.

Semi-open IP strategy/patent licensing: The inventor owns the patent rights but has shared the rights for commercially exploiting the invention to one or more of external entities through some kind of license agreement. Licensing can be exclusive or non-exclusive.

Exclusive licensing: The right to commercially exploit the invention given to a single entity.

Non-exclusive licensing: The right to commercially exploit the invention is given to multiple entities. Cases with explicit mention of exclusive license are coded under the exclusive licensing strategy. 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.

Semi-open IP strategy/Collaboration or partnership with unknown IP sharing strategy: If there is a mention of some kind of collaboration within the case descriptions, but no mention of any kind of IP-sharing mechanisms, contracts or agreements.

Fully-open IP strategy/free access to IP: The inventor allows anyone to use the IP free of charge without any commercial or use restrictions.

All the remaining cases that didn't fit in any of the above categories are classified separately as information not available.

Sample description: The green innovations represented in the sample are distributed across seven environment – related technology domains. The technological domains of EIA awarded green innovations are identified based on the OECD environment database of green growth indicators (OECD, 2016) that provide a comprehensive list of environment-related technology domain (ENV-TECH). For categorization of green innovations, standard industrial or sector classification (e.g. ISIC, NACE) cannot be used as they (a) do not provide adequate class of environment technology (OECD/Eurostat Manual, 1999), and (b) represent majorly end of pipe solution (Haščič and Migotto, 2015). Based on the description of inventions given by EIA awardees in the sample documents, we identified and classified inventions into specific technological category which are then aggregated into seven broad domains of ENV-TECH as given in Table 2.

The distribution of cases across identified technology domain is exhibited in Fig. 1. It shows that the maximum proportion (i.e. 37%) of green innovation awards are given in the domain of energy related climate change mitigation technology, followed by awards for material/plastic/packaging technology (i.e. 15%) during 2006-2019. Building and transport related climate change mitigation technologies along with environment management technology received 7 awards each. Only 3 awards are given in the domain of water related adaptation technology and biodiversity protection each in the past 13 years. It clearly shows the dominance and importance of climate change mitigation technology related to energy among green innovations.

The year wise distribution of the sample of 52 EIA awards involving green innovations across different technology domain is depicted in Fig. 2. The figure shows an overall increase in the number of green innovations in the EIA database.

Table 2 Categories of environment-related technology of EIA awards and distribution of cases

Environment technology domain	Description
Biodiversity (BD)	Life-sciences, agriculture and marine technology
Environment management (EM)	Air pollution abatement, water pollution abatement, waste management
Building and transport (BT)	Enabling technologies in buildings, energy efficiency in building, hybrid vehicles
Energy (EN)	Combustion technology with mitigation potential, enabling technologies in the energy sector, energy conversion or management system reducing GHG emission, renewable energy generation
Materials/plastic/packaging (MPP)	Industrial chemistry, material sciences, polymers, metallurgy, plastic,
Water (WA)	Water related adaptation technology, water conservation technology
Others (OT)	Laser, medical, satellite, semiconductor

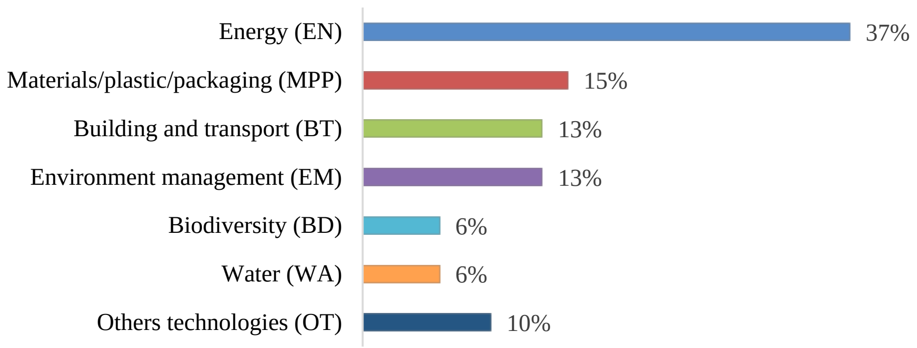

Fig. 1 Technology domain wise distribution of EIA awards for green innovation during 2006-2019 (n=52)

Out of the 52 awards for green innovations, around 77% (40 awards) are from the EU countries and the remaining 23% (12 awards) are from non-EU countries. Among the 40 green innovations that originate from within the EU, 27 have been developed by industry (including 16 SMEs and 7 large companies at the time of awarding), 10 originated from research institutions and three individual inventors. The geographical distribution of the sample is given in Fig. 3. Germany is on the top with 9 awards followed by France, the Netherlands and

Denmark. Among the awards from non-EU countries, the United States of America is on the top with 5 awards followed by Japan with three wards.

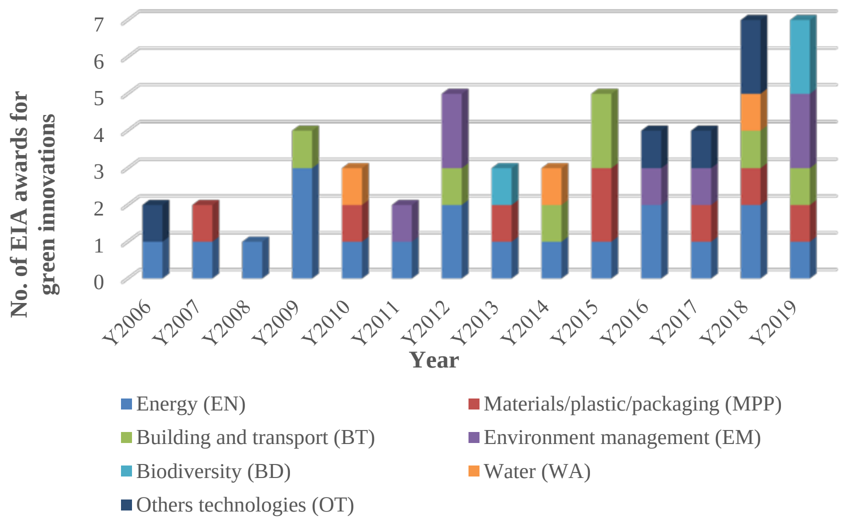

Fig. 2.Year wise distribution of EIA awards for green innovations across technology domains, time period 2006 to 2019 (n=52)

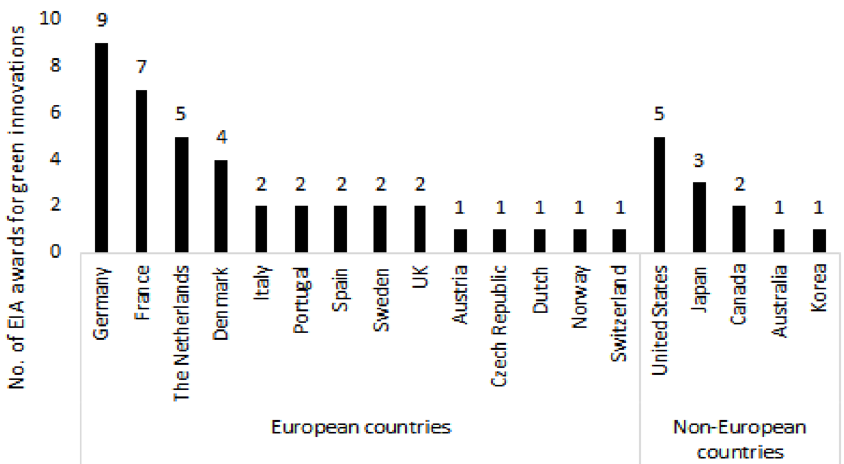

Fig. 3 Geographic distribution of EIA awards for green innovations during 2006-2019 (n=52)

4. Results

4.1 IP strategies for green innovations

Table 3 presents the distribution of different IP sharing strategies in the sample of 52 green technologies. This analysis shows that semi-open IP strategies are the preferred strategy followed by the closed IP sharing strategies, at the aggregate level. Out of the 52 cases, half (50%, (n=26)) used some form of semi-open IP strategy. Among the semi-open models licensing appears as the prominent strategy, particularly non-exclusive licensing. Out of the 15 cases that had adopted a licensing strategy, 80% (12 cases) adopted a non-exclusive form of licensing. The second most preferred strategy in the semi-open category appears to be some form of collaboration or partnership strategy. None of the cases in our sample appear to have used some kind of 'fully' open IP strategy, such as patent pledges, patent donations, and royalty free (e.g., open source) licensing.

Below we provide examples of cases to illustrate how the different IP sharing strategies were successfully used for the development and diffusion / adoption of green innovations to achieve environmental (societal at large) and economic benefits together.

Table 3: Distribution of IP sharing strategies in the sample

IP sharing strategy	No. of cases	Percentage
Closed IP strategy	**21**	**40%**
Protective and no sharing	19	37%
Patent sale / transaction	2	4%
Semi-open IP strategy	**26**	**50%**
Exclusive patent licensing	3	6%
Non-exclusive patent licensing	12	23%
Collaboration/ partnership (details unknown)	11	21%
Fully-open IP strategy	**0**	**0%**
e.g. patent pledge, patent donation, free licensing	0	0%
IP sharing details not available	**5**	**10%**

4.1.1. Examples for protective and non-sharing strategy (closed IP strategy)

The following examples illustrate different reasons and benefits of adopting closed IP Strategy for green innovations as inferred from our analysis.

Closed IP strategy for sustainability transitions, changing institutional logics, impacting long established and dominant behaviours and business models: In the area of plastic recycling, one of the biggest environmental concerns today, we find companies using closed IP strategy to contribute to transition towards a circular economy. Plastics are of different types making the process of plastic recycling complex involving sorting, cleaning and melting before processing for reuse. Owing to this complexity, "out of the 58 million tonnes of plastic waste produced in the EU every year, only 30% is recycled". Two inventors from the EREMA group, a large Austrian-based firm (founded in 1983), have developed and built state-of-the-art recycling machines that 'move, sort and filter plastic matter, delivering high-quality pellets at the end that can be used to create new products'. The company has patented the core technology of this in-house invention, called the 'Counter Current technology', and has commercialized it fully without sharing the IP with third parties. Today, 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. The two inventors hold 37 granted European patents for their recycling innovations. In the words of these inventors:

> "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." says Feichtinger. 'They [patents] have helped us in our efforts to encourage the plastics industry to move towards the circular economy." says Hackl.

Similarly, for water conservation technology inventors preferred a closed IP strategy mainly to safeguard the technology and protect their position as innovators in a field that is dominated by bigger companies. One such example is Orbital Systems that was founded in 2012 by Mehrdad Mahdjoubi (Sweden), the inventor of "Oas" a closed-loop shower system. The inventor adopted a patenting (closed IP) strategy and obtained patent protections in around 10 countries[5] not only to protect his position as an innovator in a bigger market, but also to gain confidence of bigger investors in each stage of its development process. Mehrdad mentioned that:

> "…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.".

Closed IP strategy for protection during prototype development and market launch: In the biodiversity field, inventors adopt the closed IP strategy to protect the technology during prototype development and market launch. Esben Beck is a Norway based inventor who developed a submersible robot to solve the reduced Norwegian salmon harvests problem caused by parasites. The inventor "patented the machine" in 2010 and, without sharing the IP rights with others, established a startup named Stingray Marine Solutions AS that eventually led to the development of "initial prototypes and raised more than €4 million to launch the product." Adopting a closed IP strategy helped the inventor and the previously struggling "Norway's €6.4 billion-salmon industry" to eventually become a global market leader. Thus, while adopting a closed strategy, the firm created environmental and economic impact in terms of animal welfare and job creation.

Closed IP strategy for investments from complementary industries: A closed IP strategy also helped inventors in gaining first mover advantage by attracting investments from incumbent firms from a complementary industry for development and commercialization of a protected

---

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

technology. The IP strategy helped firms to be the first mover in a new market by getting large players of a complementary industry (ie textiles) to invest in its product development and market launch. An inventor formed the company without sharing the IP with others and launched the product in 2017 by raising "EUR 25 million in investments, including backing from Karl-Johan Persson, CEO of H&M (Hennes & Mauritz), and Niklas Zennström, co-founder of Skype Technologies."

4.1.2. Examples for exclusive licensing as a semi-open IP strategy

Our analysis indicates that exclusive patent licensing is preferably used as a market entry strategy for inventions by academia or individual inventors who generally lack in-house commercialization expertise. All three exclusive licensing cases in our sample relate to inventions that originated at universities or research institutes. Exclusive licensing appears to help overcome barriers related to sustainable technology development, market entry and diffusion. The following two examples illustrate this:

Exclusive licensing strategy for commercialization of sustainable technologies from universities/ research institutions: In the field of biodiversity, exclusive licensing facilitated 'the industrial application of concrete units called Cubipods that were originally devised and patented by university researchers, who sought industry help to bring their product to market.' Menéndez Díaz Josep Ramon Medina and Esther Gómez-Martín at the Polytechnic University of Valencia in Spain invented 'Cubipod', an unusually-shaped concrete block for breakwaters that reduce erosion and provide better coastal protection. The invention was patented by the university but was not commercial ready. The patent was exclusively licensed to the industry partner, SATO that then developed a reusable mould for producing the Cubipod blocks 'in an efficient, cost-effective and flexible manner'. Together this university-industry exclusive licensing strategy has enables the protection of several ports. 'In 2018, the company was awarded a EUR 44.6 million contract to expand the port of Agaete in Gran Canaria. And 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'.

We found another case example in the field of renewable energy. The invention for easier and cheaper solar cell production by Jörg Horzel and his team from IMEC, a nanotechnology research centre in Belgium, exclusively licensed to one of IMEC's spinoffs that is said to have been very influential in the transition in the solar energy sector where 'solar-energy production has increased by an average of 40% per year worldwide since 2000'.

The third example is NEREDA, which developed a wastewater treatment and purification system. NEREDA was founded based on the patents developed by Prof. Mark van Loosdrecht and his team at the Delft University of Technology (Netherlands). Though the invention initially struggled to attract interest from existing industry collaborators, later an exclusive licensing to DHV proved to be a successful engagement for commercialization. This licensing agreement ‘involved an up-front payment, and some part of DHV´s revenues stemming from NEREDA that will return to the university in the form of licensing fees.’

4.1.3. Examples for non-exclusive licensing as a semi-open IP strategy

It appears that some form of non-exclusive licensing has been used in several of the green innovation cases. We find that the non-exclusive licensing was preferred. The following examples illustrate the reasons that speak in favour of using non-exclusive licensing.

Non-exclusive licensing for accelerated commercialization and diffusion (sustainability transition): In the materials and packaging sector, one example is the invention by the US entrepreneurs Eben Bayer and Gavin McIntyre, an environmentally-friendly biomaterial alternative to plastics that is ‘strong, delivering a strength-to-weight ratio comparable to many plastic-based products, and fully degradable in 45 to 180 days’. As of 2019, Ecovative Design, the company co-founded by these inventors has raised investments and grants of about EUR 22.1 million and employs around 45 people. The inventors have sought patent protection in 31 countries and licensing helped them expand internationally. McIntyre, one of the inventors mentioned:

> “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,”.

In the battery industry, non-exclusive licensing has transformed the battery industry when the Japanese scientist Akira Yoshino, the inventor of the lithium-ion battery, also called the “father of the lithium-ion battery”, decided to license his patented invention to manufacturers worldwide. Yoshino is a named inventor in ‘56 Japanese and six European patents’. In the words of the EPO President António Campinos:

> “His [Akira Yoshino’s] technology has transformed our society, in part because the licenses granted to other companies for the use of his patented inventions helped to decisively speed up its commercialisation.”

Yoshino’s ‘small, lightweight, rechargeable battery with a sufficient storage capacity’ are used in ‘nearly five billion mobile phones worldwide today, and have enabled the emergence of electric vehicles’. According to this inventor who transformed the battery industry,

> “…patents are not used to keep people out, rather we licence our patents to encourage many other manufacturers to use our technology. Some of my latest innovations are for batteries for electric vehicles - and these, I hope, will change the world again.”

Innovators hence appear to differentiate between ‘protection’ and ‘sharing’ aspects of IP and consider both important. A patent licensing strategy offers both strategic protection and sharing benefiting the inventor as well as the society.

Non-exclusive licensing as the core business model: Thirdly, we find that certain green innovation based companies use non-exclusive licensing as a business model for revenue generation. In the following cases, the inventors patent protected their inventions, founded and used IP licensing as the sole business model for generating revenues. Some of these firms later started their own manufacturing units, but initially relied on licensing revenues possibly to generate funds to grow the company organically.

Three cases in our sample exhibited this scenario. One is the WhalePower Corporation, a Canadain large firm that invented and patented turbines and fans inspired by whales. WhalePower "operates as a virtual intellectual property firm, licensing its designs to other companies that wish to use the technology in their particular areas of expertise." The company has its first licensed product featuring in industrial and commercial fans and blowers, an area where the global market is forecasted to be worth some EUR 8.5 billion by 2022. Another example is from the energy sector. A UK based SME named Lontra developed a technology and obtained patents for their energy-saving rotary air compressor technology. The company runs "as an intellectual property firm, licensing Blade Compressor technology for use in various industries". 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. In another example from the battery industry, the company Ovonic Battery, founded by the inventor Stanford Ovshinsky in the United States of America for his NiMH rechargeable battery invention, 'earned nearly US$ 8 million from royalties for NiMH technologies, the majority of which is related to royalties from hybrid vehicles'.

4.1.4. Examples for Collaboration/ partnerships as semi-open IP strategy

The following examples illustrate collaboration/partnership strategies for development and diffusion of green innovations.

Collaboration for technology development and scaling up: In the electrochemical fuel cell, Ballard Power Systems, a Canadian company, used collaboration with big players as a strategy to get its technology "on the road". For mass production, Ballard partnered with international automotive companies Daimler-Benz and Ford. The collaboration also has led to the birth of a spin-off company, Automotive Fuel Cell Cooperation, which later purchased Ballard's automotive division in 2007 "to expand their leading position in fuel cell technology".

Another example is the invention by Sedláček and his team of inventors at the Czech Technical University which partnered with E.On Group for testing its process. The technology is now marketed in over 16 countries under the brand names "SETUR Bladeless Turbine" and "Bladeless Rolling Turbine (BRT)".

The collaboration or partnership strategy is also found to be relevant for universities, where "...projects involved collaboration across technical and scientific fields …" and "...start-ups were launched in co-operation with former students' from the institute". Sylviane Muller, a French immunologist and the inventor of the medicine for treating lupus by targeting T-cells, marketed as Lupuzor, has co-founded two companies namely Neosystem (now Polypeptide France) in 1986 and ImmuPharma in 2002, based on her discoveries. The inventor credits a close co-operation with researcher Robert Zimmer, currently President of ImmuPharma, which resulted in a “successful transition from patented invention to a viable pharmaceutical company.”

4.1.5. IP strategies other than patent sharing

In addition to the IP sharing strategies discussed above, patent enforcement, international patenting, strategic mix of different IP types (e.g. patents and trademarks) and access to inventor know-how emerged from the case analysis as important for the success of the 52 green innovations which are all combined in parallel or sequentially. For example, the German engineer Stefan Lehnert, the inventor of the roof and cladding system using energy efficient, highly durable, light and adaptable plastic, mentions,

> “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”

Another IP strategy we observe is the strategic use of different IP types at different stages of innovation process leading to change in IP strategies over time. For example, in the case of NEREDA, the university-industry licensing example discussed above, the industry partner DHV, mentioned,

> “Patents provide a head start in a developing market... patents can provide for a certain time a trustworthy evidence of solid technology leadership. It is, however, important to build fast on this momentum and develop a branding strategy with a protected trademark ... if the momentum gained by the patents is used successfully, the value of the brand/trademark and the trust built with a larger number of reference plants can be significant. In the later run, the brand and the reputation replace the patent as value-creating tools to a large extent.”

4.2. IP strategies for green innovations across technological domains

In this section, we present the results from analysing the sample of 52 green innovation for likely variations in the IP strategy preferences across seven technology domains. Table 4 shows that the propensity to adopt semi-open IP sharing strategy (non-exclusive licensing and collaboration in particular) is higher in technological domains like material/plastic/packaging (MPP) – 62%; environment management (EM) - 57%; and energy (EN) related climate change mitigation technology – 53 %. These technology domains are given proportionally more EIA awards in the past thirteen years i.e. 15%, 13%, and 37% respectively, as compared to others.

Table 4: IP sharing strategies across seven technology domains (n=52)

IP Strategy category	IP Strategy description	Technology domains*						
		BD	**EM**	**BT**	**EN**	**MPP**	**WA**	**OT**
Closed IP strategy	Protective and no sharing	**67%**	**43%**	**57%**	**37%**	**25%**	**67%**	**20%**
Semi-open IP strategy	*Exclusive licensing*	*0*	*15%*	*14%*	*6%*	*0*	*0*	*0*
	Non-exclusive licensing	*33%*	*28%*	*14%*	*26%*	*25%*	*0*	*20%*
	Collaboration and Partnership	*0*	*14%*	*0*	*21%*	*37%*	*33%*	*40%*
	Overall	**33%**	**57%**	**28%**	**53%**	**62%**	**33%**	**60%**
Fully open IP strategy	Different forms of free IP access	**0**	**0**	**0**	**0**	**0**	**0**	**0**
Total (n= 52 i.e. 100%)		**6%**	**13%**	**13%**	**37%**	**15%**	**6%**	**10%**

Notes: *BD = Biodiversity; EM = Environment management; BT = Building and transport; EN = energy; MPP = Materials/plastic/packaging; WA= water; OT = others

We find that closed-IP strategies are adopted in technology domains where a relatively low number of EIA awards are given. For example, the number of EIA awards in the biodiversity (BD) and water (WA) domains only account for 6% of all awards. In these domains the majority of cases (67%) adopted a closed IP sharing strategy. Similarly, in the building and transport (BT) domain that accounts for 13% of total EIA awards closed IP strategies have been used in a majority of cases (57%).

To summarize, overall, the results indicate that technology domains that are more patent intensive, such as energy and materials, show higher propensity to adopt semi-open and closed IP strategies. Conversely, technology domains that are relatively less patent intensive (and are awarded less EIA awards) have higher propensities to adopt closed IP sharing strategies. A closed IP strategy offers multiple benefits to individual inventors or small firms. Some of the benefits evident from the case analysis are: protecting the firm's position as an innovator in a market dominated by incumbents, providing the first mover advantage, inducing funding support for product development and market entry from incumbents and investors and also to eventually become the market leader. Firms or inventors in environment technology domains like environment management, material/plastic/packaging and energy related climate change mitigation technology have adopted semi-open IP sharing strategies, with non-exclusive licensing being the most commonly adopted strategy followed by exclusive licensing and collaboration. Firms adopt these strategy for product co-development and market entry in the energy sector.

5. Discussion

The need to incentivize and diffuse innovations in the green sector for sustainability/climate purposes was probably made more pressing by the 2019 UN Climate Change Conference. New departments on “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 firm level however, the role of IP strategies for transition towards green and circular economy remains unclear. The findings and contributions from our empirical analysis of 52 green innovations that received EIA awards by the EPO is many-fold.

Firstly, we provide empirical evidence that choosing appropriate IP strategies is important for enabling (new/young) firms to bring green innovations to the market and subsequently create and maintain their competitive advantage. Our analysis shows that this economic incentive argument speaking in favour of the IP systems is valid as well in the context of green innovations, which are pressingly needed to be developed and diffused. Notwithstanding recent initiatives pushing for free and open IP strategies (e.g. patent pledges, open source licensing of hardware), patents remain an important tool for innovation in various green technology domains.

Whereas patents can drive innovation forward by providing incentives to recoup R&D investments, they can also slow down innovation and impede market entry. This is because patents increase returns but make follow-on innovations more costly (Boldrin and Levine, 2008). To open-up the sector and accelerate innovation, collaboration between firms through IP sharing mechanisms may be a viable option. Our literature review finds that collaboration is not easy because IPRs are one of several factors affecting the motivation to license, while other factors such as “favorable market conditions, favorable investment climate, scientific capabilities, infrastructure and human capital” seem to have a similar or even more important weight in the decision to enter into licensing agreements (Karachalios et al, 2010).

Licensing IP rights comes also with transaction costs. Although consolidated efforts to collaborate (eg Eco-Patent Commons and GreenXchange) were started to lower transaction costs for finding and negotiating contracts to use or transfer green patents, their success still remains to be proven. Mainly, the Eco-Patent Commons failed because companies did not pledge their most important patents and did not offer any service for transferring the patented technology. The GreenXchange platform and its licensing model appeared as a more feasible solution despite the lack of resources to continue ahead. Both these initiatives did not provide for a system to track the use of the licensed patents (and enable impact assessment) and lacked effective management. Nevertheless, they are relevant as a first attempt to signal the need for a change in IP management and align it with sustainability needs. In our empirical cases, we found several companies emphasizing the importance of know-how exchange along with IP transactions, an aspect that can be considered for future initiatives.

Secondly, our analysis reveals that innovators of green innovations use five IP sharing strategies but to different extents: closed IP i.e., in-house commercial exploitation without sharing the patent rights with outsiders, non-exclusive licensing, exclusive licensing, patent sale and collaboration or partnership. Our findings confirm the results of previous empirical and theoretical literature. In our sample semi-open IP strategies are adopted more often than closed IP strategies. We did not find any firm that made use of fully-open IP strategies. However, our literature review found that Toyota can be seen as an example of a company that has taken the lead to accelerate green innovation through a patent pledge, which is an example of a fully-open IP strategy, but only for a subset of its patents although the impact of this strategy remains unknown. In our empirical analysis of EIA awards Toyotas is included with its invention of a power control system for hybrid automobiles. For that particular technology, Toyota employed a closed IP strategy. Overall, in the context of green innovation, we find that companies prefer non-exclusive licensing for three reasons: for entering new markets (including their first), to accelerate diffusion of their technologies and to generate revenues by adopting an IP sharing-based business model. Exclusive licensing, on the other hand, is used by entities that lack commercialization expertise like academic universities, research institutions or individuals to bring their inventions to the market. Licensing university IP to industry has been discussed as one of the core elements in university–industry relationships (Bercovitz & Feldman, 2006). This is confirmed by our findings as well. One may, however, mention a particular risk that comes with exclusively licensing a technology with potentially large social and environmental impact to a specific company. If the technology has potentially multiple applications to benefit society, but the exclusive licensee uses only one or few of them, the technology is prevented from unfolding its full potential impact. Universities should be careful with exclusive licensing. A case where this may work is for own university spin-outs that need exclusivity to attract funding. Even in those cases universities should ensure that they have 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.

Thirdly, our analysis shows variation in the IP strategy preferences across technology domains. We were able to split the sample into seven environment-technological domains in which EIA awards are given. Inventors of energy related climate change mitigation technology and materials/plastic/packaging that together represents a large share of total EIA awards in the given period, preferably adopt semi-open IP sharing strategies. Closed IP or no sharing strategies seems to be the most preferred IP strategy in the domains of biodiversity protection, building, transport and water related technologies. These technologies, however, represent relatively few EIA awards in the past 13 years.

Finally, open innovation research has argued that firms benefit from ‘striking the right balance between sharing and protection’ (Henkel, 2006). In the context of green innovation we also find that inventors distinguish between ‘protective’ and ‘sharing’ aspects of IP and choose to tie them together for better economic, environmental and societal benefits. The coexistence of protective and sharing use of IP is evident in patent licensing. Patent is discussed as a blocking factor by providing exclusive rights to the inventors and block others from accessing the invention. Licensing however offers the flexibility to share the rights to desired third parties thereby not blocking but facilitating the exploitation of the invention by others. A patent thus can be an effective facilitator of sustainability when licensed. Protective aspect of patents can encourage green inventors to further develop their green technologies for market entry and licensing will help diffuse.

6. Conclusions

Through the analysis of 52 green innovations we provide evidence-based insights to the prevailing debates around the role of IP for sustainability transitions. Overall, we find that the strategic use of IP and sharing by firms facilitate transitions towards sustainability. From the three types of IP strategies, namely, closed, semi-open and fully-open, we find that green innovators prefer semi-open strategies, but also employ closed IP strategies. We do not find evidence that any of the economically successful green innovators who also created substantial environmental and social impact has employed a fully-open IP strategy. However, the insights into the company's day-to-day use of IP is limited to the publicly available data which we have been able to access and analyse. If one of the cases would have used open IP strategies successfully, one could assume that this would have been reported in the material compiled and published by the EPO given that open-source strategies are a "hot topic". Overall, we conclude that successful green innovators benefit from adopting and combining different IP strategies at different stages of their innovation process viz., technology development, commercialization/ market entry and diffusion.

From analysing the use of different IP strategies across seven technology domains we also find that the propensity to employ certain IP strategies varies across technology domains. This implies that the macro level initiatives and policy considerations should pay attention to technology domain sensitivities while devising a macro level IP management setup for green innovations. Rather than attempting to adopt open source models as it is that was successful in the ICT sector, our results suggest that for innovation efforts towards sustainability transition may benefit from patenting and sharing. But this needs further line of enquiry involving wider sample set.

As with all studies, this one is not free of limitations. First of all, our study is limited to data from one source i.e., 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 does not provide any insights on the fully-open IP strategies that do not involve registered IP rights. Nevertheless, we find that among the patented inventions in our data, none of the innovators adopted a fully-open IP strategy involving patent pledges or patent donations. Further studies using primary data from different sources could be useful.

Acknowledgement

The authors acknowledge Anna Quincey and Becca Clarke for their help in the initial round of data collection and coding. This paper is developed as a part of the ongoing research project IPACST and the authors thank the Belmont Forum and Norface for their funding support.

Disclaimer: The EPO has provided us with some support in finding all relevant information on the web, but has not been involved nor provided support in the analysis or preparation of the paper.

References

Abbott, F. (2009). "Innovation and Technology Transfer to Address Climate Change: Lessons from the Global Debate on Intellectual Property and Public Health." International Centre for Trade and Sustainable Development, Issue Paper No. 24.

Awad, B. (2015). Global Patent Pledges: A collaborative mechanism for climate change technology." *CIGI Papers*, *81*(81).

Barton, J. H. (2007). Intellectual Property and Access to Clean Energy Technologies in Developing Countries. *International Centre for Trade and Sustainable Development*, 1–50.

Beldiman, D. (2018). From Bits to Atoms: Does the Open Source Software Model Translate to Open Source Hardware? *Santa Clara High Technology Law Journal*, *35*(2), 23.

Bercovitz, J., & Feldman, M. (2006). Entrepreneurial universities and technology transfer: A conceptual framework for understanding knowledge-based economic development. The Journal of Technology Transfer, 31(1), 175-188.

Boldrin, M. and Levine, D., (2008) *Against Intellectual Monopoly*, Cambridge University Press.

Bonvoisin, J et al. (2017) What is the "Source" of Open Source Hardware? Journal of Open Hardware, 1(1): 5, pp. 1–18, DOI: https://doi.org/10.5334/joh.7

Bosch Eclipse. *Bosch Pursues An Open Strategy To Transform IoT,* https://iot.eclipse.org/case-studies/bosch-leadership-in-eclipse-iot/

Bowman, J. (2009) The Eco-Patent Commons: Caring Through Sharing. WIPO Magazine, https://www.wipo.int/wipo_magazine/en/2009/03/article_0004.html

Burleson, E. (2009). Energy Policy, Intellectual Property and Technology

Choi, J. (2003) Patent Pools and Cross-Licensing in the Shadow of Patent Litigation. International Economic Review 51(2):441-460.

Collura, N. (2018). A Closer Look At Tesla's Open-Source Patent Pledge. https://blogs.duanemorris.com/greenip/2018/12/04/a-closer-look-at-teslas-open-source-patent-pledge/#page=1

Consilvio, M. (2012). The Role of Patents in the International Framework of Clean Technology Transfer: A Discussion of Barriers and Solutions. *Intellectual Property Brief*, *3*(1), 7–16.

Conteras, J. L., Hall, B. H., & Helmers, C. (2019). Pledging Patents for the Public Good: Rise and Fall of the Eco-Patent Commons 1. *Houston Law Review*, *57*(1), 1–40.

Contreras, J.L. (2015). "Patent Pledges." *Arizona State Law Journal* 47(3): 543–608.

Contreras, J.L. (2016). "FRAND Market Failure: IPXI's Standards-Essential Patent License Exchange." *Chicago-Kent Journal of Intellectual Property* 15(2): 419–440.

Copenhagen Economics. (2009). *Are IPR a Barrier to the Transfer of Climate Change Technology?* 1-55.http://trade.ec.europa.eu/doclib/docs/2009/february/tradoc_142371.pdf%5Cnpapers2://publication/livfe/id/7548

Correa, C. M. (2007). "Intellectual property and competition law: exploration of some issues of relevance to developing countries." International Centre for Trade and Sustainable Development, Issue Paper No. 21. www.ictsd.org/sites/default/files/research/2008/06/corea_oct07.pdf.

de Coninck, H., & Sagar, A. (2015). Making sense of policy for climate technology development and transfer. *Climate Policy*, *15*(1), 1–11. https://doi.org/10.1080/14693062.2014.953909

Dechezleprêtre, A., et al., (2011). Invention and transfer of climate change-mitigation technologies: A global analysis. *Review of Environmental Economics and Policy*, *5*(1), 109–130. https://doi.org/10.1093/reep/req023

Dechezleprêtre, A., Glachant, M., & Ménière, Y. (2013). What Drives the International Transfer of Climate Change Mitigation Technologies? Empirical Evidence from Patent Data. *Environmental and Resource Economics*, *54*(2), 161–178. https://doi.org/10.1007/s10640-012-9592-0

Diakun, B, (2019). The pledge that may reduce Tesla's value as it seeks additional funds. IAM https://www.iam-media.com/finance/pledge-may-reduce-teslas-value-it-seeks-additional-funds

Drahos, P. (2011) Bargaining over the Climate: Lessons from Intellectual Property Negotiations. *Climate Law* 2 (1): 1–17.

Ehrnsperger, J. F., & Tietze, F. (2019). Patent pledges, open IP, or patent pools? Developing taxonomies in the thicket of terminologies. *PloS one*, 14(8).

Ellis, J. (2009). Has Toyota Turned Tesla with its Latest 'open' Patent Pledge? Not Quite. https://medium.com/@jacknwellis/has-toyota-turned-tesla-with-its-latest-open-patent-pledge-not-quite-1dee8d70d9bd

European Inventor Awards: the finalists 2019, European Patent Office Retrieved from EPO: https://www.epo.org/learning-events/european-inventor/finalists/2019.html *[Accessed 26th September 2019]*

Freeman, C. (1995). The 'National System of Innovation' in historical perspective. *Cambridge Journal of Economics, July 1993*, 5–24. https://doi.org/10.1093/oxfordjournals.cje.a035309

Gambardella, A., & McGahan, A. M. 2010. Business-model innovation: General purpose technologies and their implications for industry structure. *Long Range Planning*, 43(2-3): 262-271.

Gechlik, M. (2009). Making Transfer of Clean Technology Work: Lessons of the Clean Development Mechanism. *San Diego International Law Journal*, *11*(1), 227.

GENERAL ELECTRIC COMPANY LLC v. Mitsubishi Heavy Industries, Ltd. and Mitsubishi Power Systems Americas, Inc. (2014) https://caselaw.findlaw.com/us-federal-circuit/1665832.html

Gervais, D. (2012). "Climate Change, the International Intellectual Property Régime, and Disputes Under the TRIPS Agreement." Vanderbilt Public Law Research Paper. http://ssrn.com/abstract=2235775.

Ghafele, O'Brien.(2012). Open Innovation for Sustainability: Lessons from the GreenXchange Experience.https://www.ictsd.org/sites/default/files/research/2012/06/open-innovation-for-sustainability-lessons-from-the-greenxchange-experience.pdf

GreenXchange. http://www.greenxchange.cc/

Han, J. (2017). Technology commercialization through sustainable knowledge sharing from university-industry collaborations, with a focus on patent propensity. *Sustainability (Switzerland)*, *9*(10). https://doi.org/10.3390/su9101808

Harvey, I (2008) Intellectual Property Rights: The Catalyst to Deliver Low Carbon Technologies, Climate Change Briefing Paper. http://ianharvey-ip.com/intellectualproperty/intellectual-property-rights-the-catalyst-to-deliver-low-carbon-technologies/

Hasper, M. (2009). Green Technology in Developing Countries: Creating Accessibility Through a Global Exchange Forum, 7 *Duke Law & Technology Review* 1-14

Henkel, J. (2006). Selective revealing in open innovation processes: The case of embedded Linux. *Research policy*, 35(7), 953-969.

Hill, B. M. (2016). Powering Intellectual Property Sharing: How to Make Tesla's Patent Pledge Effective, 24 *J. Intell. Prop. L.* 191 https://digitalcommons.law.uga.edu/jipl/vol24/iss1/10

Hsieh, H.F. and Shannon, S.E., 2005. Three approaches to qualitative content analysis. *Qualitative health research*, *15*(9), pp.1277-1288.

https://www.greenbiz.com/blog/2009/07/13/greenxchange-sustainable-innovation-meets-creative-commons

https://www.wipo.int/wipo_magazine/en/2009/02/article_0002.html

Jain, A., & Ogden, J. (1999). General practitioners' experiences of patients' complaints: qualitative study. *Bmj*, 318(7198), 1596-1599.

Jeremy de Beer, (2015) "'Open' Innovation Policy Frameworks: Intellectual Property, Competition, Investment & Other Market Governance Issues." (Prepared for Industry Canada: Ottawa).

Jeyakodi, D. & Ros, M.E. (2019) The Innovation Matrix, BIS Publishers, Amsterdam, Nl.

Karachalios, K., Thumm, N., Latif, A. A., Roffe, P., Simmons, B., Amin, T. (2010), Patents and clean energy: bridging the gap between evidence and policy, Final report. Published by United Nations Environment Programme (UNEP), European Patent Office (EPO), International Centre for Trade and Sustainable Development (ICTSD).

Krattiger, A. and Kowalski, S. (2007). "Facilitating Assembly of and Access to Intellectual Property: Focus on Patent Pools and a Review of Other Mechanisms." In Intellectual Property Management in Health and Agricultural Innovation: A Handbook of Best Practices, edited by Anatole Krattiger and Richard T. Mahoney. Oxford, UK and Davis, CA: Centre for the Management of Intellectual Property in Health Research and Development and the Public Intellectual Property Resource for Agriculture.

Kumar, N. (2002). Intellectual property rights, technology and economic development: Experience of Asian countries. Research and Information System for the Non-Aligned and Other Developing Countries (RIS), New Delhi, RIS Discussion Paper no. 25/2002.

Lesser, W. (1999). Intellectual property rights and concentration in agricultural biotechnology. *AgBioForum*, 1(2), 56-61.

Machlup, F. (1958). An economic review of the patent system. Washington DC: US Government Printing Office.

Machlup, F., & Penrose, E. (1950). The patent controversy in the nineteenth century. Journal of Economic History, 10(1), 1–29.

Makower, J. (2009). GreenXchange: Sustainable Innovation Meets the Creative Commons.

Maskus, K. E. (2009). Intellectual Property and the Transfer of Green Technologies: An Essay on Economic Perspectives, 1(13) The WIPO Journal 133-137 https://www.wipo.int/edocs/pubdocs/en/intproperty/wipo_journal/wipo_journal_1_1.pdf

Merges, R. and Mattioli, M. (2016) Measuring the Costs and Benefits of Patent Pools. UC Berkeley Public Law Research Paper No. 2759027, https://papers.ssrn.com/sol3/papers.cfm?abstract_id=2759027##

Musk, E. (2014). All Our Patent are Belong to You. https://www.tesla.com/blog/all-our-patent-are-belong-you

Ockwell, D. et al., (2010) Intellectual property rights and low carbon technology transfer: Conflicting discourses of diffusion and development. *Global Environmental Change* 20 (4) 729-738.

Organisation for Economic Co-operation and Development (OECD). (2009). Eco-innovation in industry – enabling green growth. http://www.oecd.org/document/62/0,3746,de_34968570_34968855_44452670_1_1_1_1,00.html

Percival, R. V., & Miller, A. (2012). Resolving Conflicts Between Green Technology Transfer and Intellectual Property Law. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.1861340

Pisano, G. P., & Teece, D. J. (2007). How to capture value from innovation: Shaping intellectual property and industry architecture. *California management review*, 50(1), 278-296.

Reynolds, J, Contreras, J.L, & Sarnoff, J. D. (2017). "Solar Climate Engineering and Intellectual Property: Toward a Research Commons." *Minnesota Journal of Law, Science and Technology* 18 (1), 1–110.

Roberts, J. (2014) What Elon Musk did — and did not — do when he "opened" Tesla's patents. GIGAOM RESEARCH. https://gigaom.com/2014/06/14/what-elon-musk-did-and-did-not-do-when-he-opened-teslas-patents/.

Rourke, L., & Anderson, T. (2004). Validity in quantitative content analysis. *Educational technology research and development*, 52(1), 5.

Strobel, C. (2013). Wind Power and Patent Law: How the Enforcement of Wind Technology Patents May Lead to Restricted Implementation in the US, and Necessary Solutions. *19*(2).

Taubman, A. (2009). Sharing Technology to Meet a Common Challenge. *WIPO,* 2(2)

Thomas, D. R. (2003). A general inductive approach for qualitative data analysis.

Transfer to Address Climate Change, Climate Change and Human Rights Symposium. *18 University of Iowa Transnational Law and Contemporary Problems, 69.*

Van Overwalle, et al.,. (2006). "Models for Facilitating Access to Patents on Genetic Inventions." Nature Reviews Genetics 7 (2): 143–54.

Van Hoorebeek, M. & Onzivu, W. (2010). The Eco-Patent Commons and Environmental Technology Transfer: Implications for Efforts to Tackle Climate Change. *Climate Change Law & Regulation* (1) 13–29.

Vimalnath, P., F. Tietze, E. Eppinger and J. Sternkopf. Open, semi open or closed? Towards an intellectual property strategy framework. Presented at the 19th *European Academy of Management (EURAM) Conference*, Lisbon (Portugal), 26-28 June 2019.

WIPO (2008) Climate Change and the Intellectual Property System: What Challenges, What Options, What Solutions?" Informal Consultation Draft 5.0. Geneva: WIPO. www.wipo.int/export/sites/www/policy/en/climate_change/pdf/ip_climate.pdf.

WIPO (2009) Patent Pools, Sharing Technology, *WIPO Magazine*, *special edition* (2).

WIPO (2014) Patent Pools and Antitrust - A Comparative Analysis, https://www.wipo.int/export/sites/www/ip-competition/en/studies/patent_pools_report.pdf

WIPO Green. https://www3.wipo.int/wipogreen/en/

WIPO, 3(4) https://www.wipo.int/wipo_magazine/en/2009/03/article_0004.html

Zhou et. Al, 2018, Comparing the International Knowledge Flow of China's Wind and Solar Photovoltaic (PV) Industries: Patent Analysis and Implications for Sustainable Development https://www.mdpi.com/2071-1050/10/6/1883/htm