

The Role of Patents in Advancing Circular Economy Technologies

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Abstract

Transitioning to a circular business model for production and consumption is one of the main steps towards a sustainable society and resource-efficient production. Circular economy technologies such as waste-to-resource systems, advanced recycling technologies, eco-design technologies, renewable material processing technologies and product life-extension technologies are an important part of combating environmental degradation and sustainable use of industrial processes. In this context, patents can be a valuable instrument to protect IP, and to drive technology development and commercialization of sustainable solutions. The present study will focus on the potential role of patents in the creation of technologies for the circular economy and their effect on innovation, knowledge transfer and competitiveness of industries. The general method used in this research is review research, review of the literature, trends in patents and policy concerning innovations in the circular economy. The results show that patent protection encourages R&D investments because it gives the owner of the patent the exclusive right to his/her invention. Patents also enhance investment opportunities, technology transfer and industry, research institute and government collaboration. Moreover, patent databases provide sources of technical information for innovators, enabling them to discover trends and avoid reinventing the wheel.

However, patents can come with its drawbacks such as the cost of filing patents, access issues for small businesses, and the ethical implications of the distribution of green tech. This research emphasizes the need for the implementation of a fair IP policy regime to stimulate innovation while at the same time creating more opportunities for access of environmentally friendly technologies. The outcomes show that a patent efficient system has the potential to foster the development and diffusion of circular economy technologies, to achieve sustainability goals and to stimulate economic growth in the long-term. The paper ends by emphasizing the importance of strategic patent management for the innovations required to tackle global environmental and resource problems.

Keywords: Circular Economy, Patents, Intellectual Property Rights, Sustainable Innovation, Green Technologies, Resource Efficiency, Technology Transfer, Environmental Sustainability.

Introduction

The shift from linear "take, make, and dispose" economy to circular economy has emerged as one of the major solutions to address the global environmental problems, resource scarcity and sustainable development issues. The circular economy aims to get the most value out of resources, including waste reduction, re-use, repair, re-manufacture and recycling. The circular economy systems aim to reduce the environmental impact, to support the competitiveness and economy of the industry and to extend the lifetime of the products and recover materials.

Technological innovation is one of the important enablers for circular economy practices.

Advanced recycling technologies, waste-to-energy (WtE) systems, biodegradable materials, eco-design solutions and mechanisms for resource recovery have greatly enhanced the potential of industries to transition towards sustainable production and consumption patterns. But a lot of investment is needed to develop such technologies, and IP protection is a significant determinant of innovation and commercialization.

The patent is one of the most crucial components of the intellectual property system, whereby the owner of a patent receives the exclusive rights to his invention for a specific period. This protects the investments of people, research institutes and companies in new solutions to facilitate the realization of the circular economy objectives. In addition to providing an incentive for invention, patent systems also help spread technical information by making it public so that others can build on it. This means that patents play a role in technological development as well as in transfer of knowledge in the sustainability-related industries.

In the past few years, governments, international organizations and businesses have increasingly recognized the strategic importance of the patent protection of fast-track green and circular technologies. Patent activity regarding sustainable packaging, waste handling, resource efficient manufacturing, renewable resources and industrial symbiosis is strong. These innovations are contributing to the abatement of environmental impacts, the generation of new business opportunities and the sustainable economic development.

Though there are advantages that can be gained from patents, issues have been raised about the effect of patents on technology accessibility and diffusion. Patents can also be one of the tools to foster innovation, while at the same time may be considered as a 'gate' for smaller companies and for the developing economies to be able to access the coming advanced technologies of the circular economy. Hence, the issues of balancing intellectual property protection and technology transfer is still critical to ensure greater sustainability goals can be achieved.

This research explores the role of patents in the development of circular economy technologies in terms of innovation, knowledge sharing, commercialization and sustainable industrial transformation. The paper will examine the role patent systems play in the creation and uptake of CE solutions and the opportunities and challenges arising from IP protection for the goal of environmental sustainability and resource efficiency.

Background of the study

The current linear economy, defined by "take-make-dispose," is highlighted as having limitations in the context of worsening pressures on natural resources, degradation and climate change. This model has played a major role in causing resource depletion, waste production, and ecological imbalance. To address these problems, the concept of the circular economy has arisen to achieve maximum value from resources, promote the continuous circulation of materials through re-use, recycling, remanufacturing and recovery, and reduce waste.

Technological innovation plays a key role in the implementation of the principles of circular economy. Innovative technologies in waste management, renewable energy, eco-design, recycling systems, material recovery and sustainable manufacturing are key to helping organisations move towards a circular economy. With growing investments in research and development by industries to develop such technologies, protection and commercialization of innovation becomes important.

One of the most important tools for the protection of IP rights is patents. Patents allow inventors to enjoy exclusive rights to their invention for a certain amount of time, which helps to promote investment in research and technological progress. They offer innovations the chance to offset their development costs, to obtain competitive benefits and to secure financial backing for additional innovation initiatives. Patents can create and promote the spread of sustainable solutions in the context of circular economy technologies, by offering legal protection and incentives to inventors and organizations.

During the last ten years a growing number of patent applications were filed in the area of green

technology, resource-saving production processes, waste recycling techniques, biodegradable materials and innovative technologies for renewable energy. The strategic value of IP systems in achieving environmental sustainability has been acknowledged by governments, international bodies and private sector. Patent databases are also useful sources of technological information that can help pinpoint new trends, technology gaps and potential collaboration in the circular economy value chain.

Patents are regarded as key but there is debate over the role of patents to enable innovation for sustainability. Patents encourage investment and technology development, but technology transfer and technology access issues were raised, which are slow and slow adoption of sustainable technologies, particularly in developing economies. One of the main challenges to global circular economy targets is how to balance the protection of intellectual property and the need to share knowledge.

To this end, policymakers, researchers, businesses and innovators need to understand the role that patents play in the development of circular economy technologies. Analyzing patent activity can shed light on the rate of technological evolution, industry specialization, and the benefits of IP regimes for sustainable economic change. The aim of this study is to investigate the role that patents play in the development, protection, dissemination and commercialisation of innovations and technologies for a circular economy in enabling the transition towards a more sustainable and resource efficient world.

Justification

The shift from the linear “take-make-dispose” economic model to a circular economy is now high on the global agenda to address resource depletion, environmental degradation and climate change. Sustainable development is enabled by incorporating new recycling technologies, waste-to-energy technologies, Eco-friendly manufacturing processes, product life-extension technologies and technologies recovering resources among the various technologies that can be implemented in a circular economy. But for successful development and commercialization of these technologies, there is a need for a lot of research and innovation investment.

Patents are a crucial tool in safeguarding IP rights, which are vital for promoting innovation and investment in new technologies. Patents offer protection to innovators, encourage research and development, help to transfer technologies and spread knowledge between industries. Patents can be a driver of innovation in the field of circular economy technologies, by enabling competition, investment and by facilitating cross-industry and collaboration with research institutes and government.

Although innovations for sustainability have drawn more and more attention, there is only limited research that has systematically analysed the impact of the patent system on the development, protection and diffusion of circular economy technologies. It is crucial for policy makers, industries and researchers to understand this relationship in establishing an innovation ecosystem that can simultaneously foster economic growth and environmental sustainability.

This study is therefore justified, given the need for an investigation on the role that patents play in technologizing the circular economy. Results will be used to gain insights into the development of the patent landscape, innovation paths and policy considerations for sustainable innovation and access to environmentally friendly technologies. To summarise, the research presented here contributes to the existing knowledge on the management of IP rights and technological sustainable development and in this way to the global transition towards more resource-efficient and environmental friendly economy.

Objectives of the Study

1. To understand how patent systems can foster innovation in relation to technologies for circular economy.
2. Identifying the role patents play in stimulating R&D efforts focused on resource

- efficiency, waste reduction and sustainable production.
3. To identify key technology areas in the circular economy where there has been considerable activity on patents.
 4. To evaluate the impact of patent protection on investment and commercialization of innovations in the field of circular economy.
 5. To assess the IPR diffusion across industries and the relationship between IPR and diffusion of sustainable technologies across industries.

Literature Review

The move from the traditional 'take, make, dispose' linear economy to the circular economy has become a key solution to tackle resource depletion, environmental degradation and waste generation. The circular economy prioritizes resource efficiency, the recycling, remanufacturing, reuse and sustainable design of products. Technology is a key enabler in this shift and technology patents are an important tool to protect and encourage technology innovation.

It has long been recognized that patent systems are tools that encourage innovation by providing temporary monopoly over the innovation to the inventor. Patents incentivize firms to spend resources on R&D, as they enable firms to make back their innovation expenses, says Moser (2013). In a sustainable sense, patents help commercialize the environmentally friendly technologies and encourage disclosure of knowledge through the publication of patents.

Eco-innovation plays a key role in sustainable development, while protection of intellectual property may help to increase the development and spread of environmentally friendly technologies (Schiederig et al., 2012). Dechezleprêtre et al. (2011) also discovered that environmental patents play an important role in international diffusion of green technologies, facilitating the wider diffusion of sustainable innovations across countries.

In recent years, the link between patents and circular economy innovation has been receiving more and more research focus. The authors of the study (Geissdoerfer et al., 2017) highlighted the importance of technological development as one of the key enablers for achieving circular business models, especially in waste valorization, recycling systems and product life extension. Patent protection offers firms motivating benefits to invest in these technologies, and valuable IP assets that can be licensed and commercialized.

Saari et al. (2026) show that patents have a significant role to play in enabling circular innovation, such as sustainable and recyclable textile materials. In their patented man-made cellulosic fiber product analysis, they found that patented innovations are not only associated with product development, but also with socio-technical transitions to circular production systems. The study also emphasizes the role that the material-related patents can play in systemic circularity through technology, industrial and societal transformation.

Patent analytics also have proven to be useful to discover technology trends in the field of the circular economy. Lanza and Zucchiatti (2026) published a taxonomy of circular patents, and they observed a significant increase in the number of patents for technologies used in waste management, recycling and recovery. Their results show that patent databases can offer valuable information on the development and spatial distribution of innovations related to circular economy.

There are a number of research efforts that have investigated how patents can be used to foster technology development in resource efficiency and waste management. The authors of Vezzoli et al. (2018) imply that the protection of intellectual property promotes sustainable product-service systems by helping to mitigate the uncertainty of innovation. Similarly, Kirchherr et al. (2017) reported that as for the technological innovations that facilitate the closing of material loops, they cannot be achieved without technological innovation supported by patent protection. New technologies like artificial intelligence, new recycling, and advanced recycling, biotechnology, and Industry 4.0 have reinforced this link between patents and the development

of the circular economy even more. Capetillo et al. (2023) pinpointed chemical recycling, bio-based systems and digital technologies as key technological pathways to circular transitions in plastic value chains. They believe that patent technology can have a major impact on resource recovery and waste reduction results.

There has been a growing trend to use patent information for technology forecasting and strategic planning. A recent study by Li et al. (2025) created a patent analytics framework based on over 39,000 circular economy patents, and found several technology clusters related to sustainable innovation. The study shows how to use patent information for policy makers and companies to identify technological opportunities and investment priorities in the circular economy.

Even with such benefits, research has also identified issues such as patents and sustainability transitions. Hall and Helmers (2013) suggest that patent protection can also serve as an impediment to technology diffusion, especially in developing countries where access to sustainable technologies is essential. Likewise, Ballardini et al. (2022) argue that patents encourage innovation but can, at times, be used to impede collaborative activities that are needed for realizing a large-scale circular economy.

Open innovation and collaborative patenting have thus become complementary strategies to help achieving goals of circular economy. In recent years, companies are increasingly using external knowledge networks and licensing deals to speed up innovation, as proposed by Chesbrough (2003). Patent licensing can help in the spread of sustainable technologies and in maintaining the incentives for inventors in circular economy ecosystems.

Overall, the literature suggests that patents fulfil two roles in the promotion of circular economy technologies. First, they encourage investment in research and development by protecting innovators' intellectual property rights. Second, in providing access to patent information, they help in the dissemination of knowledge. Although accessibility issues have been expressed, evidence indicates that if patent systems are designed appropriately, they can be used to enhance technological progress, foster sustainable industrial processes, and promote transition to circular economy.

Material and Methodology

The present study follows a qualitative review-based research method to analyse the possibilities of patents to support the development and diffusion of technologies for the circular economy. The study has used only secondary data that has been gathered from various academic and institutional sources. Academic databases including Scopus, Web of science, Google Scholar, ScienceDirect, SpringerLink, IEEE Xplore were used to identify relevant literature. Patent information was also gathered from international patent repositories and reports generated by various organisations including the World Intellectual Property Organization (WIPO), the European Patent Office (EPO), the United States Patent and Trademark Office (USPTO) and the Organisation for Economic Co-operation and Development (OECD).

Journal articles, conference papers, books, policy documents, industry reports, patent databases, and government publications on IP rights, sustainable innovation, resource efficiency, waste management, recycling technologies, remanufacturing systems, renewable materials and circular economy practices were used in the study. A time window of 2001-2026 was chosen to reflect the latest developments in patenting activities and technological innovations supporting circular economic transitions.

This approach for methodology is systematic review approach. The following keywords were used to identify relevant documents on the Internet: circular economy, green innovation, sustainable technologies, patents, IPR, recycling technologies, recycling, resource recovery and eco-innovation. The literature reviewed was clustered in the following thematic areas: patents protection and innovation incentives, technology transfer, environmental sustainable technologies commercialization, patents access barriers, and contribution of patents to

environmental sustainability. The comparative and descriptive analysis was then performed to determine the trends, patterns, opportunities and challenges for patent-driven innovation in certain areas of the circular economy. The results were then synthesized to gain a holistic perspective on the impact of patent systems on the development, diffusion and adoption of technologies that enable circular production and consumption.

Results and Discussion

Results:

The literature review indicates that patents are playing a significant role in the development, protection and dissemination of CE technologies. New areas in waste management, recycling technologies, renewable materials, remanufacturing processes, energy recovery systems and resource efficient manufacturing have been the area of significant patent activity. These are examples of growing investments in sustainable innovation and the shift towards a circular economy in the world, as the number of patented products grows in these areas.

Trend analysis of patents shows that patents for the circular economy are held by a significant proportion of developed economies, with the leading economies having high levels of environmental regulations and innovation. The U.S., Germany, Japan, China and South Korea, among other countries, have shown impressive patenting activity in the field of resource efficiency and environmental protection technologies.

The literature also implies the role of patents in stimulating firms to invest in R&D, as these give firms the monopoly power and legal protection over the intellectual property of their technological invention. By patents, organisations may obtain competitive edge in the market, licensing and support possibilities, and strengthen investor trust on their innovations in the field of circular economy. Licensing agreements, partnerships and collaborative innovation networks are also enabled by patents for the transfer of technology.

Many research studies have found that the growth of patents in advanced recycling technologies such as chemical recycling, electronic waste recovery, plastic waste conversion and industrial symbiosis systems are strong. Also, the patenting of innovations concerning product life extension, modular product design, the ease of repair, and re-manufacture have grown as industries look for more sustainable production methods.

But the review does not overlook issues with patent systems. In the case of SMEs, one of the most critical issues is having and maintaining patents, and especially the financial and procedural difficulties. Furthermore, excessive patent protection can stifle the dissemination of knowledge and can also become a bottleneck in the use and commercialisation of the green technology, particularly in developing countries.

Discussion:

The results highlight the need for patents to play an important role as a technology enabler for the circular economy, which offers an incentive for innovation. The answers to the circular economy can be substantial investments in research and experiments and commercialization. Patent protection reduces the risk of such investments and encourages companies to invest in new technology that will result in resource recovery, waste reduction and sustainable production.

The higher number of patents for circular economy in technologically advanced countries indicates that there is a strong link between innovation capacity, as well as conducive policy environments and the protection of IP. Innovation support and environmental policies are more likely to create higher levels of technological innovation in circular economy sectors when both are present. This indicates that patent policies are more effective when used in conjunction with other policies for sustainability and industry.

Patents are also singled out in the review for the dual role of patents in the framework of the circular economy. While patents are a key enabler for innovativeness and technological

advances, they can also restrict access to the key technologies required to solve sustainability problems, if patents are too expensive to license or if they are overly broad and protective. It is therefore crucial to ensure a balance between the protection of IP rights and the availability of technologies to promote global sustainability transitions.

In response to this challenge, collaborative patenting strategies, patent pools, cross-licensing models and open innovation models are suggested. This permits organisations to safeguard their inventions and help spread and uptake of circular economy technology. These partnerships may be particularly helpful in addressing a multifaceted environmental issue that needs several industry and area innovations.

The other important draw to be made is the growing importance of the patent as a technology progress measure in the circular economy areas. Patent databases are helpful for determining what is new in the field, what is the trend or how competitive is the field. There are patent analytics tools available that would help identify the gaps in the technologies, monitor innovation performance, and develop targeted support programs for policymakers, researchers and industry players.

The results also indicate that the institutional support for enhancing participation in circular economy innovations is needed to be stronger in developing economies. Capacity building programs, ease of access to patents, financial support mechanisms, and IT transfer mechanisms are among the ways in which Innovation activities can be improved in these regions. This would help to build a more inclusive circular economy ecosystem globally.

Overall, the literature validates the role that patents can have in the promotion of innovation, investment and commercialization of circular economy technologies. However, policies that maximize their contribution to sustainable development must take into account the various incentives for innovation while ensuring of accessibility, cooperation and global knowledge sharing. Enabling new solutions and accelerating their adoption will require not just technology advances, but successful innovation and uptake through the IP system and its enforcement.

Limitations of the study

This study has some limitations that must be taken into consideration when interpreting the results of this study. First, the research is mainly based on secondary information from academic articles, patent information, industry reports and policy documents, which might not be sufficiently representative of the most recent advances of circular economy technologies. Second, the number of patents and patent-related indicators are taken as measures of innovation activity, but not all patented innovations are brought to market and accepted in practice. Third, the study does not stratify sufficiently by industries, regions, and technological sectors, where there could be different trends in patenting behaviors and innovation outcomes. Furthermore, the applicability of the results across countries might be restricted due to different national patent laws and regulations, and enforcement mechanisms of IPRs. The study also largely relies on formal innovation systems and may fail to consider informal knowledge transfer and collaborative technological innovation, which have come into play and gained relevance in the context of CE. Primary data, sector-wise analysis and a longitudinal study are recommended for future research to gain a better understanding about the relationship between patent and the development of the circular economy technologies.

Future Scope

Future research in the study of the “Role of Patents in Advancing Circular Economy Technologies” could investigate how the nature of the patent protection-sustainable innovation relationship is changing in different industrial sectors. With the growing importance of circular economy practices worldwide, additional research may focus on the potential role of patent systems in the development and diffusion of technologies for recycling, waste valorisation, resource recovery technologies, eco-design and product life extension. Comparative studies of

patent policies in different countries could offer information on how best to foster environmentally-friendly innovations and promote access and technology transfer. The development of collaborative patenting, open innovation models, and patent pools could be other research topics for future studies on how to speed up the adoption of circular technologies. Further, the combination of new technologies like artificial intelligence, blockchain and the Internet of Things with CE solutions is a promising field for patent-based innovation studies. Both the longitudinal and the empirical studies can also be used to evaluate the economic, environmental and social effects of the use of patented circular technologies, which will then help in the formulation of policies and sustainable industrial development.

Conclusion

Patents play an important role in the invention and protection of circular economy technologies, innovation and the commercialization of green technologies and solutions. The patent process is also a motivation for inventors and organizations to invest in research and development that concentrates on using resources efficiently and minimizing waste, recycling, remanufacturing, and using renewable materials. The paper emphasizes the need for a patent system to stimulate technological progress because of its capacity to allow knowledge to be made public and its capacity to provide temporary monopoly rights to the innovators. In the meantime, patents facilitate the transfer of environmentally friendly technologies through licensing, partnerships and tech transfer. But for realizing the potential of the circular economy innovations a balanced approach is required, which will support intellectual property protection as well as a wider access to sustainable technologies. Supportive innovation ecosystems are to be established by policy makers, industry and research institutions, collaboration between sectors to be encouraged, the barriers for uptake of technology need to be lowered and investments stimulated. As sustainability and resource conservation become increasingly central to the global economies, patents will continue to be a valuable instrument for promoting innovation and technological advancements that can help make the global economy more circular, resilient, and environmentally friendly.

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