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Analysis of green innovations: a patent data study

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CONTENTS

INTRODUCTION

Innovation is to be considered macroscopically as a driver of economic and social progress, while microscopically it is a motor of corporate success and the subsequent competitive advantage of the firm. Indeed, according to economist Michael Porter: *"innovation is the central issue of economic prosperity"*. However, in order to reduce climate change with the ultimate goal of realizing a world with more sensitivity towards environmental problems, it is essential to promote the development of green innovations. These innovations make it possible to safeguard the planet by creating new ways to deal with issues arising from climate change and simultaneously decrease the use of energy and resources.

The purpose of the present thesis is to conduct a study concerning the current state of the art regarding green technologies and provide an overview from the perspective of innovation activities. The work has been divided into four major parts plus a conclusion chapter.

In the first, there is an outline of what is meant by the concept of green innovations, its characteristics and a brief overview of patent data in the green field over the past few years.

Meanwhile, in the second chapter, the focus is on the notion of patent and its basic features up to the discussion of the International Patent Classification (IPC).

The third chapter firstly starts by drawing attention to the database used in the elaboration, which is Derwent Innovation, and then shifts the look to the two green classifications that are the subject of investigation in this thesis (IPC Green Inventory WIPO and Y-TAG EPO), and as a last step the queries used for dataset extraction are explained. Setting the time frame of analysis (2015 to present day) and focusing on the European market will complete the framework.

Finally, the fourth chapter is dedicated to providing the analysis. It first provides a more general overview regarding the quantitative results obtained for each group of the two classifications under consideration, and then after displaying the general background information, two categories for the IPC Green Inventory classification and two groups for Y02 are analyzed in further detail. In fact, the databases for the latter will be extracted and analyzed on Excel to obtain additional analysis on time trends and major players. An

Average Citation Index of innovations for each company will then be offered to evaluate their portfolios and reveal the leading companies for each group under consideration.

In the fifth and final chapter, there is the conclusion, which will briefly summarize the main results obtained in the previous chapter.

CHAPTER 1: Green innovations

Historically, many countries have prioritized economic development, focusing entirely on the principle of profit maximization, without concern for environmental consequences. Over the years, this attitude has produced serious problems of pollution and high levels of energy consumption. As a matter of fact, we have reached a point where the progressive damage to the environment has affected the collective interests of humanity and, in particular, has interfered with the rhythm of social and economic progress.

Nowadays, the world is facing more and more increasing and urgent environmental pressures, among which there is the increasing loss of biodiversity, the incessant production of waste, climate change, the depletion of natural resources, and finally, the increasing water and air pollution. Internationally, numerous policies and initiatives in green sectors have emerged to deal with these issues. In this regard, in September 2015, the governments of the 193 member countries of the ONU signed the 2030 Agenda, an action program for people, planet and prosperity. It incorporates 17 SDGs (Sustainable Development Goals, see Figure 1 for the detail on the different goals) into a broad program of action, promoting the achievement of a total of 169 goals. The launch of this sustainability program has coincided with the beginning of 2016 and all countries have committed to achieving the SDGs by 2030. The main objective is to protect the planet from constant degradation, through conscious use and production, managing the natural resources present in a sustainable manner and taking urgent measures with respect to climate change, so that not only the needs of present generations, but also of future ones, can be fulfilled.

Figure 1: The Sustainable Development Goals, adopted on 25 September 2015 as a part of the 2030 Agenda.

Source: https://commons.wikimedia.org/

More generally, the growing increase in environmental laws not only forces states to devote more attention to initiatives in this area, but also provides incentives for companies to embrace green sustainability in their business models. Therefore, a key issue for companies becomes the focus on corporate sustainability and in order to integrate this crucial issue into their strategies, firms must try to aim at producing specific innovations that also have positive outcomes on the surrounding environment. Hence, innovation, or rather the creation and dissemination of new ideas, is to be considered as a pivotal point in the transition to a healthier and cleaner global environment. In particular, green innovations, a set of innovative practices involving a new process, an advanced product, and recent systems are needed to achieve a reduction in environmental degradation. These green innovations can be applied in a variety of areas, such as: manufacturing, natural resource utilization, water supply and treatment, waste management, electricity distribution and storage, and many others. The long-term goals of these innovations are to reduce pollution, save energy, effectively manage environmental externalities, and improve the environment in order to create a resource-efficient, climate-resilient, and environmentally friendly society.

In the successive paragraph, the concept of green innovation, which represents the object of study of this elaboration, will be analyzed in detail, as well as its advantages and peculiarities with respect to other innovations.

1.1 What is intended by "green innovations"?

Firstly, in order to proceed with the development of this thesis, it is necessary to clarify the concept of green innovation, to fully understand what is meant by the use of this term. The literature employs a variety of terms to refer to green innovation: ecological innovation, environmental innovation and sustainable innovation. These terms are used without distinction due to the fact that they are related to the same topic and may be used interchangeably. In fact, the three different notions of green, ecological and environmental innovation are widely used as synonyms in most publications on this topic, while a slight difference can be found with the notion of sustainable innovation, which expands the concept to include a social dimension. A series of definitions for the four notions outlined will be reviewed hereafter.

Beginning with the definitions regarding green innovation, there is a quite pragmatic one elaborated, in 2002, by the two experts Driessen and Hillebrand, in which they state that green innovation *"does not have to be developed with the goal of reducing the environmental burden"*[1]. Four years later, Chen, Lai et al. described green innovation "*as hardware or software innovation that is related to green products or processes, including innovation in technologies that are involved in energy-saving, pollution prevention, waste recycling, green product designs, or corporate environmental management*"[2].

On the other hand, regarding eco-innovation, one of the first definitions dates back to 1996, when Fussler and James assert that eco-innovations are to be identified as *"new products and processes which provide customer and*

[1] Driessen P.H. and Hillerbrand B.*, Adoption and diffusion of green innovations. In Marketing for Sustainability: Towards Transactional Policy-Making*, Amsterdam, IOS Press, 2002.

[2] Chen Y.S., Lai S.B., Wen C.T., *The influence of green innovation performance on corporate advantage in Taiwan*, J. Bus. Ethics, 2006.

business value but significantly decrease environmental impacts"[3]. Kemp and Pearson, in 2007, will also provide a definition very similar to the previous one of eco-innovation, defining it as *"the production, assimilation or exploitation of a product, production process, service or management or business method that is novel to the organization (developing or adopting it) and which results, over its life cycle, in a reduction of environmental risk, pollution, and other negative impacts of resource use (including energy use) compared to relevant alternatives"*[4].

In relation to the definitions of eco-innovation, Oltra and Saint Jean define environmental innovation, as follows: "*innovations that consist of new or modified processes, practices, systems and products which benefit the environment and so contribute to environmental sustainability*"[5]. This definition includes all changes in the product portfolio or production processes that facilitate the achievement of environmental objectives and considers the effect of innovation activities without regard to the initial intent, including both incremental and radical improvements. In fact, innovation can be incremental, which means small, incremental adjustments to the existing product or process, or it can be a radical innovation that leads to a new method of creation, that does not build on existing innovations.

Ultimately, sustainable development is defined by Brundtland report, as *"the needs of the present without compromising the ability of future generations to meet their own needs. The concept of sustainable development does imply limits - not absolute limits but limits imposed by the current state of technology and social organization on environmental resources and the ability of the biosphere to absorb the effects of human activities"*[6].

As one may notice, the above definitions show some minor differences one from the other, the most striking difference can be seen in Brundtland's quotation on sustainable development, in which a social sphere is also outlined in comparison to the previous ones. In addition, it is clear that they

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[3] Fussler C., James P. A, *Breakthrough Discipline for Innovation and Sustainability*, Pitman Publishing, London, 1996.

[4] Kemp R., Pearson P., *Final Report Mei Project about Measuring Eco-Innovation*, Um-Merit: Maastricht, The Netherlands, 2007.

[5] Oltra V., Saint Jean M., *Sectoral systems of environmental innovation: An application to the French automotive industry*., Technol. Forecast. Soc. Chang., 2009.

[6] Brundtland G. H., *Report of the World Commission on Environment and Development: Our Common Future.,* World Commission on Environment and Development, New York, 1987.

all refer to the same topic and for this reason the different notions, as already mentioned at the outset, can be considered as synonyms and be used, then, interchangeably.

Furthermore, Schiederig et al.[7], thanks in part to the various definitions mentioned above for this area of innovation, were able to outline six essential aspects of green innovation, which are outlined as follows:

1) Object of innovation: which may consist of a product, a process, a service, a method (e.g., business model or marketing for the promotion of certain products).
   By the object of innovation can also be distinguished two major categories of green innovations (GI), namely the Product GI and the Business - Process GI. The former concerns a new or improved good or service that leads to significant environmental improvements over the good or service previously produced or used by the company. While Business - Process GI is a business process that is also new or improved for one or more business functions that has been put into use by the company and that generates environmental improvements over previously used business processes. These two types of green innovations are not mutually exclusive, in fact, a GI could be both a product and a business process at the same time;
2) Market orientation: meaning that the innovation should satisfy needs or solve a problem and therefore be competitive on the market;
3) Environmental aspect: in other words, reducing negative impact (i.e., fewer negative externalities). The optimal situation would be reached with the achievement of zero impact on the environment;
4) Phase: the entire life cycle must be considered in order to reduce material flow;
5) Impulse: that is, whether the reduction intention turns out to be economic or ecological;
6) Level: establishing a new green innovation or standard for the company.

These aspects that have just been mentioned are necessary for the implementation of proper environmental management aimed at addressing various business issues, such as: the use of non-renewable resources, waste disposal and management, and others.

[7] Schiederig T., Tietze F., Herstatt, C., *Green innovation in technology and innovation management—An exploratory literature review,* Res. Dev. Manag., 2012.

It is also important to point out that green innovations can occur not only in green industries, which means in sectors where environmental protection is the core business of the main company, such as material recycling companies, renewable energy generation and storage facilities, or natural products manufacturing companies, but also in companies located in traditionally non-green sectors or with a product portfolio filled with goods that are not green. Obviously, implementing green innovations is a major challenge for these non-green companies because it often requires the acquisition of new resources and skills that differ significantly from existing ones. These new skills can be more easily and cost-effectively developed by non-green industries by creating, for example, technology and market partnerships to mitigate internal weaknesses.

1.1.1 Advantages and distinctive features of green innovations

The attention to environmental sustainability, as mentioned previously, is now an essential topic for both green and non-green companies. In fact, companies are gradually changing their attitudes, not only because they are forced to do so by stringent national and international regulations or by the pressure of consumers, who show more sensibility towards eco-sustainable products, but also because the adoption of environmental management strategies creates profitable opportunities for innovative investments and business development. Therefore, a correct mix between technological and green innovations allows companies to maintain a foothold in a constantly evolving market and, at the same time, to safeguard the planet through the use of non-polluting processes.

In the following, the main strategies adopted by companies towards green innovations will be analyzed in order to understand their advantages and disadvantages. Mainly, the tactics used by companies regarding sustainable innovation can be divided into two major macro-categories:

- Passive, also known as "wait and see" strategies. These techniques are adopted by all companies that refuse to change, since they consider environmental investments only as an expensive cost and therefore do not consider new market opportunities, leaving innovations in this area to be developed by other companies. Companies that adopt this method are in an almost wait-and-see position, linked to the behavior

of competitors, their respective governments and stakeholder expectations.

Most of the companies that use these strategies are non-green companies, as the high level of costs required to upgrade their production processes to be environmentally friendly is a solid barrier to entry for the latter.

In addition, a factor such as the lack of strong government commitment to environmental protection in many countries can exponentially increase the temptation to adopt this "wait and see" tactic. It must be considered, however, that those companies that undertake a passive strategy are aware that they may lose market share, as they are voluntarily giving up the opportunity to develop technologies and will always have to adapt and follow the leading companies, who have believed and invested in green innovation.

- Active, these, on the other hand, are the tactics undertaken by companies that actually carry out innovations that respect and benefit the environment. Obviously, the risk for such companies is the same as taking on the full risk of investing in innovation, but it is important to point out that, in the case of success, they can benefit from all the consequent advantages of being a first mover. In fact, good green innovation improves market position, establishes the brand, outperforms the competition and, above all, attracts new customers.

In other words, companies are well advised to take an active profile from the point of view of green innovation, specifically because environmental innovations can provide crucial support to companies both to strengthen their economic objectives and to create or consolidate their competitive advantage. In fact, it must also be considered that sustainable innovation is closely associated with corporate environmental management and the achievement of ecological goals, precisely because of this, green innovation is believed to stimulate environmental performance. In summary, green innovation should be viewed not only as a reactive fulfillment of government demands, but as a proactive practice to gain competitive advantage and improve corporate performance.

Furthermore, although green innovations cannot in most cases immediately increase short-term profitability, they may create long-term economic benefits for the company. These advantages are due to the fact that green innovations not only reduce negative environmental impact, but also increase

the economic and social performance of a company through reduced costs and waste, a reduction in material consumption and production time.

On the other hand, another point of advantage for these innovations, is the growing awareness of consumers about the environmental impact of their choices of consumption, which can lead consumers to assume an attitude of brand loyalty towards companies that choose to support and protect the environment.

After the overview of the advantages that can be obtained through a positive approach to green innovations, it now seems necessary to clearly highlight how environmental innovations differ from other types of innovation, at least for two different main aspects, that are: the specific externalities and the specific drivers, which are at the base of their development.

In fact, Rennings in one of his works[8] states that environmental innovations differ from others because they generate two externalities. The first is a negative externality and is constituted by the so-called spillovers of knowledge generated, which benefit competing firms and reduce the incentive for companies to invest in innovation, since they cannot fully appropriate the value created. But it must also be considered that green innovations also generate positive environmental externalities, in fact, the value created by cleaner technologies leads to considerable cost and pollution savings, to which are added the following other benefits:

- the reduction of the company's environmental impacts, achievable through the reuse and recycling;
- the resolution of the company's environmental problems, that means less use of potentially harmful components;
- the development of environmentally friendly products and processes, that is, less usage of resources and energy.

The second major difference is the fact that green innovations are not self-enforcing and, therefore, a key role is played by policy interventions to drive their introduction. In fact, unlike other types of innovation that involve demand-pull and technology push factors, the determinants of green innovations are generally induced by regulation.

[8] Rennings K., *Redefining Innovation - Eco-Innovation Research and the Contribution from Ecological Economics*, Ecol. Econ., 2000.

1.1.2 Types of green innovation

In this sub-section it is intended to briefly analyze how companies can generate green innovations, based on their existing market and technical capabilities. In order to accomplish this goal, we employ the "The Innovation Landscape Map" developed by Pisano (Figure 2), in which the skills and business models required for the implementation of innovations are linked through the use of a four-quadrant matrix. As it can be noticed, the map introduces the degree of innovation along two dimensions: on the abscissas the degree that involves a change in the technology and on the ordinates the degree that requires a variation in the business model.

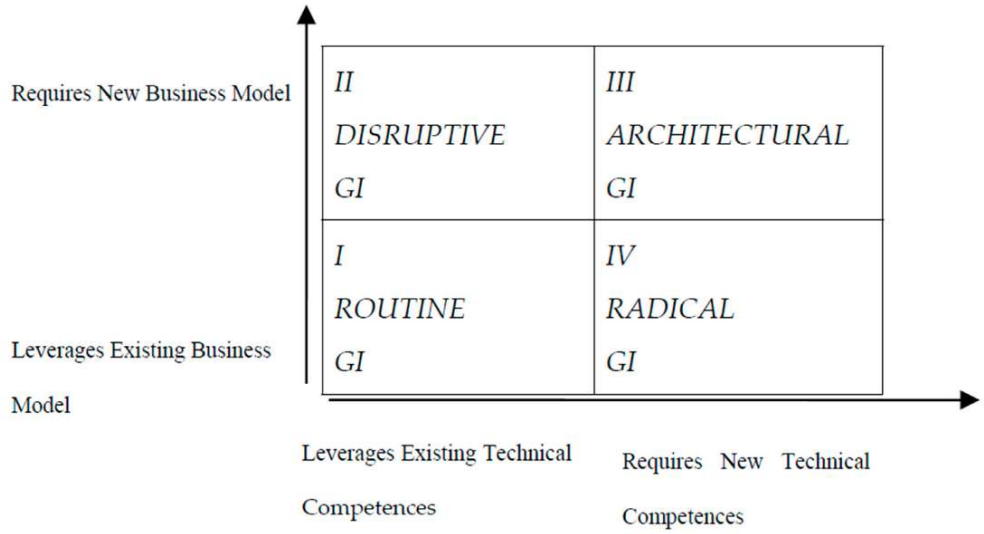

Figure 2: The Green Innovation Landscape Map.

Source: Pisano G.P., *You Need an Innovation Strategy*, Harv. Bus. Rev., 2015

Pisano identifies four quadrants, or categories, of innovation. The first is routine green innovation, which uses the company's existing technical expertise and a business model consistent with its market segment. It is typical of companies that have been in the same industry for years, whose production, even if standardized, still manages to generate green innovation thanks to the economy of experience gained.

In the second quadrant are disruptive green innovations that use the company's pre-existing technical expertise but adopt a new business model. In this typology, the company needs to establish partnerships with other players to develop the new market for its products or services. These

innovations make environmentally sustainable improvements to products or services in a way that the market does not expect, while also influencing competing companies, who are required to react to avoid losing market share.

Meanwhile, in the third quadrant, green architectural innovation takes its place, which is achieved by combining new technical skills with a new business model. It is characteristic of those companies that implement a true internal revolution since they play outside their current technological and market domains.

In the fourth and last quadrant there is radical green innovation, which is the opposite of disruptive innovation and presents a purely technological challenge. The latter, in fact, is developed with new technical skills while maintaining the existing business model. So, in this case, the company needs to find a technology partner to achieve the required technical skills. The most important role is entrusted to the management, which must be able to make its employees perform at their best and find the best combination of resources to generate more efficient processes or new green products, while preserving the original structure.

1.2 Tackling climate change nowadays thanks to green innovations

After considering the meaning of the term green innovation, its characterization, and how companies can implement it, it is now crucial to obtain a clear view of current climate change and which concrete initiatives governments are using to tackle it and, most importantly, how these affect the development of environmental innovations.

The largest human-caused contributor to climate change is fossil fuel, which is used as a major energy source for electricity and transportation. Indeed, it can be seen that since 1970, carbon dioxide (CO_2) emissions from human activity, especially fossil fuel combustion and industrial processes, have contributed approximately 78%[9] of global greenhouse gas (GHG) emissions. The main greenhouse gases are: carbon dioxide (CO_2), water vapor (H_2O),

[9] IPCC, 2014: *Climate Change 2014: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 2014.

nitrous oxide (N_2O), methane (CH_4), and ozone (O_3). These gases absorb and re-emit heat into the atmosphere, affecting the rate at which the climate changes. A striking fact, as shown in the Figure 3, is the increase in global emissions of greenhouse gases and carbon dioxide over time, with increasing growth rates recorded since 2006. Confirming this growth is an OECD analysis[10], which suggests that global GHG emissions are likely to increase over 70% by 2050.

In other words, global warming represents a serious danger for the growth of

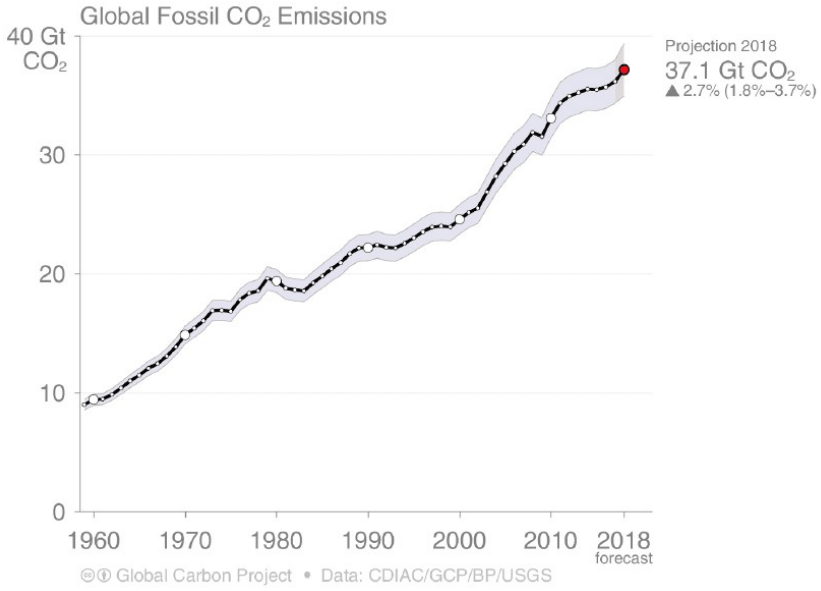

Figure 3: CO_2 emissions over the years.

Source: https://www.globalcarbonproject.org/

the economy and for the sustainability of life on our planet. In fact, because of the latter, extreme weather events occur, whose annual global cost is estimated by the World Bank to be $520 billion in lost welfare[11].

Governments are justifiably putting more and more effort into tackling and combating climate change. In 2015, through the Paris Agreement, 196 countries pledged to contain the rise in global temperatures to less than 2°Celsius (C) by the end of the century and preferably to halt the rise at

[10] Machiba T., *Sustainable Manufacturing and Eco-Innovation*, Synthesis Report OECD, 2017.

[11] *World Intellectual Property Report 2022 The Direction of Innovation*, WIPO, 2022.

1.5°C.[12] Afterwards, in 2021 in Scotland, more specifically in Glasgow, the same countries reaffirmed this commitment, and some, including the EU (European Union), China, Argentina, South Africa, the United Kingdom, and the United States, agreed to tighten their existing plans to further limit emissions. The European Union, for example, will target to reduce GHG emissions by at least 55% by 2030, from the 40% originally proposed. In addition, the EU in 2019 launched its European Green Deal, which has the ambitious goal of making Europe carbon neutral by 2050. To make this possible, about 35% of the €100 billion budget of Horizon Europe, the EU's research and innovation program, will be dedicated to tackle climate change. China is also moving in this direction and has announced net zero emissions by 2060, while India has expressed the same objective by 2070. It is clear, however, that in order to achieve such ambitious climate goals in the time scale of a few decades, all countries will have to make massive investments in environmental technologies and a strong change of path away from polluting technologies.

1.2.1 Incentives and taxes

To encourage green innovation, governments are using subsidies, regulations, and standards. Since the mid-1970s, in fact, global public R&D funding for energy sources has shifted away from fossil fuel investments (see Figure 4). In fact, according to reports from the International Energy Agency (IEA), public funding for fossil fuels has declined by nearly half over the time period between 2010 and 2020, from 13% to 7% of total public energy R&D spending.[13] Obviously, partly due to this, companies are increasingly investing and adopting in green technologies, which are to be considered as the technologies of the future. The U.S., for example, through Joe Biden's $1.85 trillion infrastructure bill, "Build Back Better," will allocate $555 billion to combat climate change, including $300 billion for 10-year tax incentive systems to encourage wind, solar, nuclear and electric vehicles.

[12] https://unfccc.int/process-and-meetings/the-paris-agreement/the-paris-agreement/key-aspects-of-the-paris-agreement

[13] IEA, *World Energy Outlook* 2020.

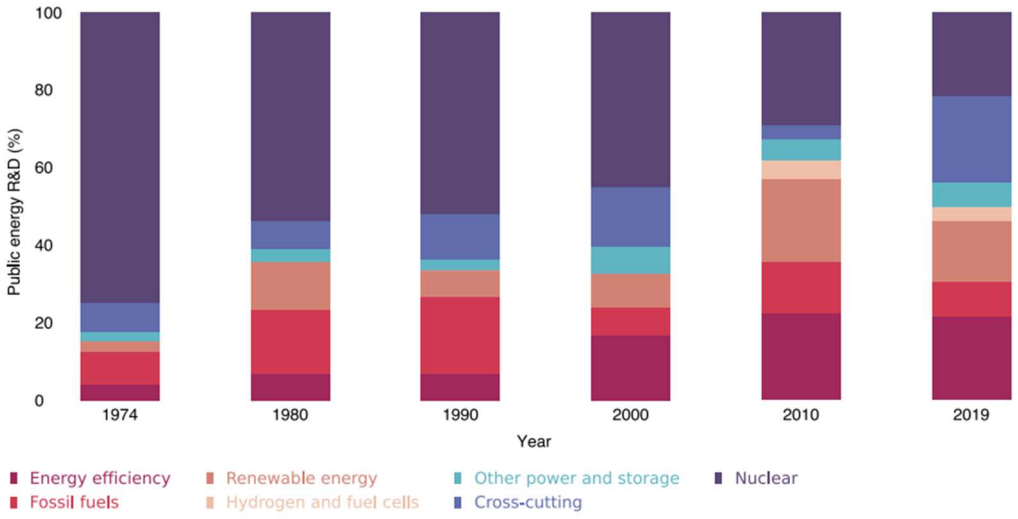

Figure 4: Share of public energy R&D investment spending by technology in percentage, 1974-2019.

Source: IEA, World Energy Outlook 2020.

Further mechanisms, which facilitate the adoption of environmentally sustainable technologies and move consumers away from dependence on fossil fuels, involve carbon taxes. The World Bank has reported that about 45 nations are currently implementing carbon pricing initiatives, through emissions trading schemes, emission reduction funds and carbon taxes[14]. In addition, the United Nations Framework Convention on Climate Change (UNFCC) has shown that about 100 countries are considering carbon pricing as their national strategy to reduce CO_2 emissions[15].

In conclusion, government standards, rules, and regulations play a key role in the adoption of green technologies by both industry and households. As a result of these standards, in fact, demand for these green technologies has been created, and according to reports from the International Renewable Energy Agency (IRENA) in the timeframe between 2013 and 2018, the private sector accounted for 86% of renewable energy investments globally[16].

[14] https://carbonpricingdashboard.worldbank.org/

[15] https://unfccc.int/about-us/regional-collaboration-centres/the-ciaca-initiative/about-carbon-pricing#eq-6

[16] IRENA and CPI, *Global Landscape of Renewable Energy Finance*, International Renewable Energy Agency, Abu Dhabi, 2020.

1.2.2 Green patents

According to the previous paragraphs, governments are increasingly aiming to direct research into green innovation. The idea of what is considered green, however, is constantly evolving and depends on the challenges and achievements already made towards the green economy. Technologies that are considered green today may not be considered green in the future.

In order to define green innovations in a better way, the OECD has developed a classification scheme. This categorization includes: climate change mitigation technologies (CCMTs) for energy, transportation, and buildings; adaptation technologies related to water; environmental management (air, water, and waste pollution); and capture and storage of greenhouse gas emissions. Mitigation technologies are also called low-carbon technologies because they generate relatively lower CO_2 emissions than energy generated through the use of fossil fuels. Concrete examples in the field of energy production can be wind turbines or photovoltaic solar energy, while in transport practical examples are electric vehicles.

To fully understand the evolution of environmental technologies over time, it is necessary to look closely at trends in patenting activities for these technologies. Currently, environmental patents account for only a small share of total patenting activities, about 6% of global patent families in 2019. From Figure 5 that follows, it is possible to observe the trends in patents covering all groups of environmental technologies over time. As shown in the chart, after the initial great growth in the 1970s and 1980s, patents regained a slower growth rate in the 1990s. Thereafter, the industry saw exponential growth in the time frame from 2000 to 2010, where the number of patent families increased from 10,000 to 30,000 per year, an impressive 3-fold increase in just 10 years.

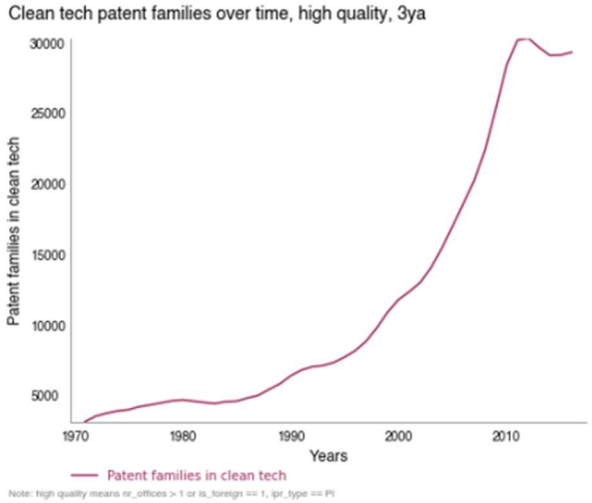

Figure 5: Global evolution of patenting activities in environmental technologies.

Source: Noailly J., *Directing innovation towards a low-carbon future*, Economic Research Working Paper No. 72, WIPO, 2022.

In a deeper look at specific technologies (Figure 6), the striking increase in environmental technologies since 2000 is due principally to the rise of energy-related CCMTs. Patent families in this technology group represent approximately one-third of the entire environmental innovation. Subsequent larger groups consist of patents in environmental management, and CCMTs in buildings and transportation.

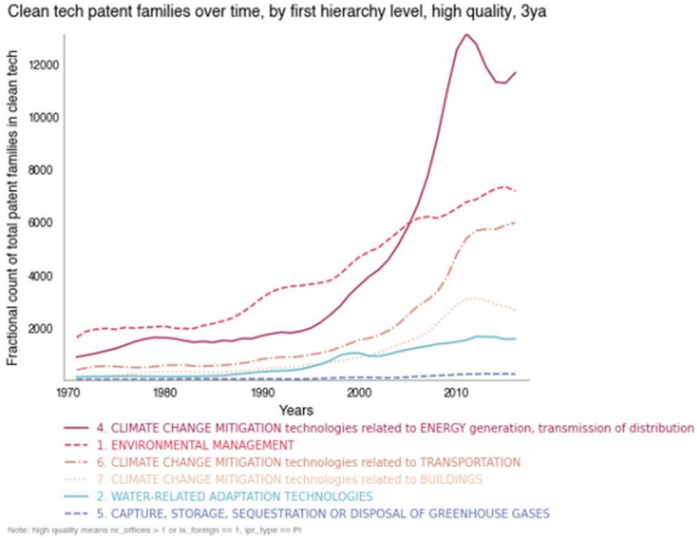

Figure 6: Global evolution of patenting activities, per category of environmental technologies.

Source: World Intellectual Property Report 2022 The Direction of Innovation, WIPO, 2022.

Then finally, Figure 7 with an even greater level of detail shows that the strong growth in energy-related CCMTs is associated with renewable energy sources such as solar, wind, and fuel cells. According to the report prepared by the United Nations Environment Program and Bloomberg NEF, solar energy-related patent applications increased dramatically in 2019, contributing to more than half of all renewable energy patents. In particular, wind energy and geothermal energy contributed 28% and 14% of total patents, respectively.[17] These data show that in these last few years the focus has shifted to green technologies and investments made in the renewable energy sector continue to grow year by year.

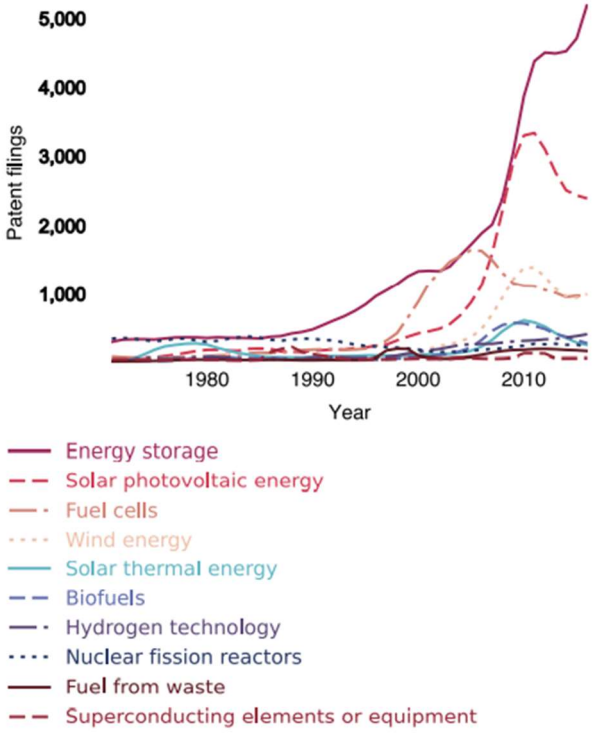

Figure 7: Climate-change mitigation technologies in energy by subcategories.

Source: World Intellectual Property Report 2022 The Direction of Innovation, WIPO, 2022.

[17] Loran S., Osani M., *A decade of renewable energy investment, led by solar, tops USD 2.5 trillion*, United Nations Environment Programme, 2019.

Focusing now on our country, environmental inventions constitute on average 9,6% of the total number of patents deposited in Italy in the last 10 years. It is possible to see from the Figure 8 the trend of patent applications over the years, shown as a percentage of total patent filings. In 2013-2014 there is a decrease of 1%, probably due to the reduction in investment in R&D caused by the economic crisis, but after there is a positive trend with an increase in patent filings from 2014 until reaching 10,6% in 2018. These data show clearly how Italian companies are more and more aware of sustainability.

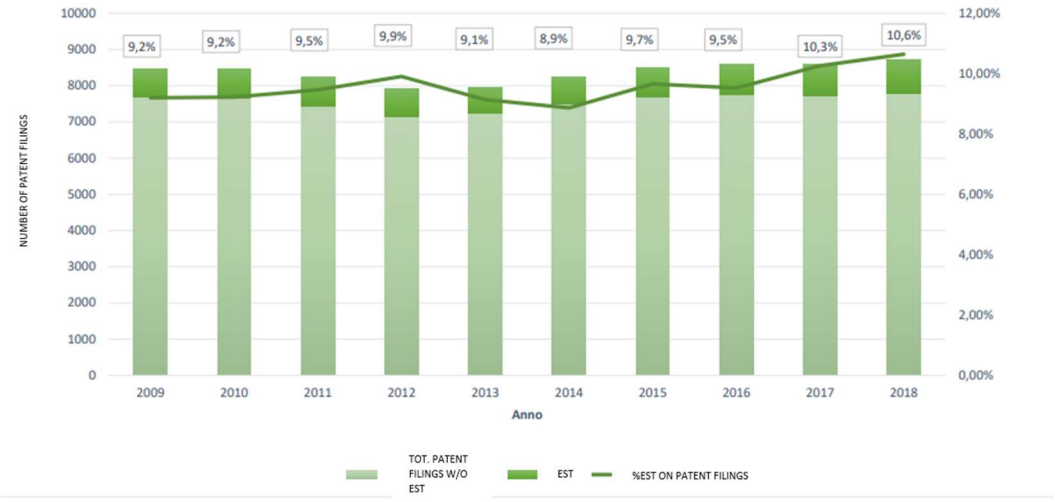

Figure 8: Patent filing trend in Environmentally Sound Technologies.

Source: I dati sul numero di brevetti green in italia. Un'analisi UIBM sui dati dei brevetti presentati nel campo delle tecnologie eco-sostenibili, Direzione Generale per la Tutela della Proprietà Industriale Ufficio Italiano Brevetti e Marchi Divisione VII-Brevetti, 2020.

CHAPTER 2: The patent system

In the absence of patents, the innovative projects developed in the green field would not be profitable, since anyone could easily copy the invention of others and make it unfairly their own. In order to properly understand the analysis of this thesis project, it is essential to comprehend how the patent system works and which are the elements that constitute a patent.

Historically, the first evidence that can be gathered of a law concerning patents dates back to the year 1474, when the Senate of Venice established a decree in order to stimulate innovation and to safeguard inventors. In order to be patented, the invention had to fulfill the condition of being new for a given region and the consequent patent was effective for a maximum of 10 years. Furthermore, it is relevant to point out that at that time the specifics of the invention were not made public.

Nowadays, the primary objectives of the international patent system are to ensure innovation and to encourage information sharing, so that people can learn from each other. In fact, when an invention is patented, the pertinent information is made public in order to promote the development and propagation of new knowledge, while protecting patent owners by providing protection for their inventions. Thus, in present days, patents have a divulgation purpose since the publication of a patent allows other inventors or companies to benefit from the invention and improve existing technologies, promoting technological advancement and the development of innovative technologies.

2.1 The patents

The World Intellectual Property Organization (WIPO), which is the United Nations agency that promotes the protection of intellectual property worldwide and ensures administrative cooperation among intellectual property unions, defines patents as follows: *"Patents are intellectual property rights for the protection of an invention in the territories of individual jurisdictions which may be granted in exchange for disclosure of the*

invention".[18] Indeed, an essential aspect of patent law is that it is not the same worldwide, but differs by jurisdiction. Therefore, the rules for requesting a patent and for handling applications, the ways of requesting deposits and even what can be considered to be patentable or unpatentable may be different and should be considered according to the jurisdiction.

Considering the Italian legislation, in the Industrial Property Code, it is stated that: *"Inventions in any field of technology which are new and which involve an inventive step and are capable of industrial application may be patented"*[19]. From this definition emerges the concept of innovativeness, which is one of the fundamental requirements that an invention must meet in order to be eligible for patent protection, in fact, in order to claim the patent it is mandatory that the invention in question is new and therefore has never appeared anywhere else in the world. In addition, to be considered new, there must be no prior public disclosure of the invention before the date of deposit. Other requirements that the invention must satisfy to be eligible for patent protection are the following:

- Level of invention, i.e., the patent must deal with something that is not trivial and obvious to a person expert in the pertinent technical field, but above all that attests a step forward from the current state of the art;
- Fabricability, in other words the concrete possibility of producing and applying the invention for practical purposes. In fact, an invention, in order to be patentable, cannot be purely theoretical;
- Lawfulness, which means not violating morality and public order (Art. 27.2, TRIPS Agreement);
- Sufficient disclosure, in fact the application must reveal the invention clearly enough for the invention to be carried out by a person skilled in the art.

It is important to underline that there are, in the majority of legislations, technological fields which are excluded from the patentability scope (art. 27.3, TRIPS Agreement), such as: scientific theories or mathematical methods, computer programs, discoveries of materials or substances already present in nature, diagnostic or therapeutic and surgical methods for the treatment of human beings or animals. However, there are exceptions to these

[18] Trippe A*, Guidelines for Preparing Patent Landscape Reports*, World Intellectual Property Organization (WIPO), 2015

[19] Art. 45, Codice della proprietà industriale, D.lgs. 10 febbraio 2005, n.30, *Oggetto del brevetto*.

limits, for example, a program may be patentable if its use involves technical and physical results within the hardware. "Technical result" means, for instance, if the application of the program results in a different and more efficient management of the memories inside the device, then such program may be patented.

Patent rights are usually limited to a period of twenty years from the date of registration and once they expire there is no possibility of renewal, consequently the invention will then become part of the public domain. During this time frame, the patent gives its owner the right to exclude third parties from manufacturing, using, selling and importing the invention and to profit from it. Therefore, if someone is interested in using the invention, he will have to pay the owner of the invention an economic compensation, which is typically a percentage of the profits produced by the invention. In addition, the ownership of a patent can also be transferred to a third party as if it were a tangible asset, and the new owner will enjoy all the rights held by the previous owner up to that moment. Both of the above transactions of licensing and assignment of a patent are governed by the contractual rules set forth in the jurisdiction where the transaction takes place. Furthermore, it is important to point out that it is not the responsibility of the State, but rather of the patent owner to identify and take action for any infringement of its patent rights.

Since, as has been seen, a granted patent represents the legal right to exclude third parties from exploiting the invention in the specified jurisdiction, unless the owner consents, then it can be asserted that the patent has a commercial value, which can only be exploited by the one who holds it. This is the reason why patents are sometimes referred to as a "limited monopoly" based on their ability to prevent competitors from entering a market or making use of a patented technology. Thus, owning patents can be considered a barrier to entry into certain markets.

2.1.1 Components of patent document

The following subsection will examine the composition of the patent documentation. The information that is gathered on each single patent, regardless of the country of origin, is organized into three major sections: bibliographic data, description of the invention and claims. Each of these

subdivisions is in turn broken down into subsections that offer more detailed and specific information about each significant aspect of the patent.

The bibliographic data section is typically located on the first page of a patent document and defines the basic elements of the technical content of the document. Generally, statistical analyses, such as patent landscapes, focus on the analysis of this section. The main bibliographic data are listed below:

- Applicant: the physical or legal entity that deposits the patent, who is also the holder of the patent rights if the request is accepted. If the application is approved, the applicant is called assignee;
- Inventor: a single person or group of persons who are the authors of the invention that is the subject of the patent. However, it is important to note that the inventor does not possess the rights arising from the concession of intellectual property;
- Filing date: decided by the patent authority and it establishes the limit within the state of the art will be analyzed to determine whether the invention meets the conditions for patentability. Furthermore, through this information it is also possible to establish the expiry date of the patent itself;
- Priority date: the date on which an applicant deposits a patent relating to a prior published patent. Specifically, the date on which the applicant refers to the priority of that previous application;
- Publication date: the date on which the patent is published, usually 18 months after the patent application is deposited or 18 months after the first priority date. Represents the date on which the patent takes effect and begins to exercise at least provisionally its warranty effect, although it has not yet been granted;
- Priority data: composed of the patent application number, the date of the application for the deposit, and the identification of the nation/organization to which the applicant made a prior application for the deposit. It identifies any prior patent applications on the basis of which a priority claim is made;
- Classification: its purpose is to organize published patents according to technological areas of belonging. This classification was introduced by WIPO in 1968 and is called the IPC (International Patent Classification) classification. This subsection will be analyzed in more detail later in section 2.2 since it will be relevant for the following analysis;

- Citations: covers the state of the art related to the patent in discussion. Citations may suggest collaborations between more inventions. Studying them can be useful in identifying which inventions will have the greatest technological impact.

The central part of a patent documentation is identified by the description, which defines the technical aspects concerning the invention. In most cases it provides a summary of the technical background of the invention and outlines the main aspects of the invention, usually using drawings to facilitate understanding for a reader.

Lastly, the third section represented by the claims outlines the scope for which protection is sought or granted. Thus, they specify what an applicant claims as his or her own invention. The first claim of all is called the main claim and includes the technical features of the invention that help solve the initial problem, which brought birth to the invention. It is important to note that at least one claim must be provided in patent applications.

2.1.2 Patent deposit process

With the submission of the deposit documentation to the Office of First Filing (OFF) begins the process of depositing the patent, subsequently there may follow successive deposits of the same invention at other offices, in this case called Offices of Second Filing (OSF), this happens in order to obtain protection in more jurisdictions. Patenting abroad serves primarily to broaden the spectrum of licensing opportunities for foreign companies, but it is necessary to take into account the onerous costs, so it is advisable to select in detail the countries for which apply for patent protection.

It is important to highlight that some patent authorities keep the application secret until the grant of filing, while others publish patent applications 18 months after the filing date or, after the priority date if it is a Second Filing Office.

Publications by First Deposit Offices are referred to as pre-grant publications and do not yet represent a granted right; in fact, this right may never be granted because the application may be withdrawn or abandoned so that the invention becomes public knowledge in the jurisdiction where the application was filed.

A special type of patent application is the Patent Cooperation Treaty (PCT), a multilateral treaty administered by the WIPO, which has effect in as many as 152 jurisdictions and allows an applicant who intends to file a patent in multiple territories to easily do so with a single application. In fact, in this case once the application is filed with a national, regional patent office or with the International Office in Geneva, an international supplemental search report will be obtained that will examine the patentability of the invention. At this point, the applicant has a period of 30 months to make an informed decision on whether to obtain protection in member country jurisdictions.

2.2 The IPC codes

The International Patent Classification (IPC), was established by the Strasbourg Agreement in 1971 in order to obtain a single classification of patents throughout the world. In fact, before this codification, each legislation had its own classification system and each of these systems was in its own national language, obviously leading to extreme confusion and making very complicated to access patents published in other countries. Currently the IPC is used by more than 100 nations and patent authorities, the classification is updated periodically by a committee of experts, composed of both representatives of contracting states and organizations, such as the European Patent Office (EPO). The IPC provides a hierarchical system of codes for classifying and searching patents and utility models, but it is also used for publications, scientific articles and technical texts in general.

In this classification, inventions are classified on the basis of functional characteristics rather than possible applications. The IPC divides patentable technologies into eight sections (A - H), representing the technological field to which the patent belongs, and these in turn are divided into increasingly detailed levels (subsections, classes, subclasses, groups and subgroups).

Each symbol in the classification is of the alphanumeric form, the first letter representing the "section" consisting of one letter from A ("Human Necessities") to H ("Electricity"). In particular:

- A, Human Necessities: this section groups together all those patents that affect human needs, such as agriculture, food, personal items, health and sports;

- B, Performing Operation and Transporting: identifies various chemical and physical processes in order to perform separation and mixing operations of solid materials, liquids or gases. Also included in this section is metalworking, printing, and finally a subsection devoted to transportation and microstructural and nanotechnology;
- C, Chemistry & Metallurgy: includes organic chemistry, inorganic biochemistry and water treatment, oil, coal, gas, ferrous and non-ferrous compounds;
- D, Textile & Paper: covers materials such as natural, man-made and synthetic textile fibers and the systems for processing these such as stitching, weaving, cutting, molding and the systems for processing pulp and papermaking;
- E, Fixed construction: involves systems for the construction of railways, bridges, roads, water systems. This section also includes all earth and rock drilling methods and related mining;
- F, Mechanical Engineering, Lighting, Heating, Weapons and Blasting: pertains to patents about the mechanical industry, specifically engines and parts thereof, pumps and methods of operation. Included in this section is also what concerns lighting and heating;
- G, Physics: in this category are inventions that exploit physical properties/characteristics, such as size, temperature and density;
- H, Electricity: essentially groups together all applications of an electrical nature, hence basic electrical elements, electrical generation, electronic circuits, radio and electrical communication techniques.

Each of these sections contains a subsection, which defines in a more specific and detailed way the sector to which it belongs. In addition, the sections are divided into numbered classes, which provide the second technology level of the classification. Each class symbol consists of the section symbol followed by a two-digit number.

Each class in turn includes one or more subclasses, which provide the third technology hierarchy level of the classification. These are represented by the class symbol with the addition of a capital letter.

Lastly, each subclass is partitioned into groups, which can in turn be divided into subgroups. Those represent the fourth hierarchical level, which is the lowest level.

CHAPTER 3: Search strategy

The Patent Landscape Report (PLR) is referred as a patent overview report and presents an all-around outlook of patent activity and trends for a specific field of technology. Hence, a PLR provide a clearly and intuitively understandable set of information regarding the performance of a specific technology. In most cases, enterprises employ PLRs as a preliminary analysis to both implement strategic decisions on research and development investments and to observe and monitor the activity of their major competitors.

Obviously, to create a PLR requires firstly the definition of the study sample, the creation of the latter is the main topic of this chapter. In the following paragraphs, attention will first be focused on what are the main patent databases from which the information necessary for the analysis of this thesis work can be obtained. Then, once the patent repositories have been defined, attention will shift to creating several queries to extract from the selected patent database the study samples, on which the analysis will be performed.

3.1 Patent databases

Patent-related databases store the relevant information contained within each individual field of patent documents. Therefore, almost all the information that can be found on patents is extrapolated and reported in patent databases, which are mainly available to consult online. This makes it easy for innovation seekers to use these databases and interrogate patent data using search queries, which is a combination of keywords and specific filters.

Both government and private entities offer patent databases. As an example, the European Patent Office (EPO) and WIPO possess patent databases that can be consulted online. In specific, WIPO has PATENTSCOPE[20], which can be consulted freely on the organization's website, the latter of which has a user-friendly interface and within it encloses most of the information contained in patent documents.

Several states of the world likewise have their patent documents indexed in government-owned databases, all of which are characterized by open access

[20] https://patentscope.wipo.int/search/en/search.jsf

and the possibility of being browsed online. Consider, for example, official Italian, U.S. and Korean patents are stored in UIBM[21], USPTO[22] and KIPRIS[23] databases, respectively.

In addition, as previously anticipated, private companies also provide online patent database services, in this case the service offered can be either paid or for free. Google Patents[24] or PatentInspiration[25] are some examples of cost-free databases, however, both do not allow advanced analysis, unlike paid databases that provide more accurate analysis.

3.1.1 Derwent Innovation

Derwent Innovation[26], i.e., a paid, privately owned patent search platform by Clarivate Analytics, will be used to carry out the analysis required for this thesis work. The web application provides access to all international patent databases, and involves the use of queries, which allow the user to set filters on a large number of fields ranging from the title of the patent to its description, assignee name, etc.

Clarivate's database employs DWPIs (Derwent World Patents Index), in other words, these represent reliable patent information extracted from filed documents, that avoid the need to consult the individual original patent document. Thus, it offers the great timesaving benefit of obtaining the most out of patent data, without the need to go through the entire document for research. In addition, consider that the DWPI team of more than 900 editors analyzes, extracts and indexes approximately 90,000 new patent publications every week, and that Derwent is currently in use by more than 40 patent offices around the world to be able to, not only evaluate new patent

[21] http://brevettidb.uibm.gov.it/

[22] https://www.uspto.gov/patents/search

[23] http://www.kipris.or.kr/enghome/main.jsp

[24] https://patents.google.com/

[25] https://www.patentinspiration.com/

[26] https://clarivate.com/products/ip-intelligence/patent-intelligence-software/derwent-innovation/

applications, but also to be able to settle disputes that arise between inventors[27].

The Derwent Innovation database uses a user-friendly interface, in other words, it is easy to understand and intuitive for the average user and consists of many buttons and filters. The following Figure 9 shows the web design of the web interface, in which two tabs for patent searching can be distinguished (Patent search and Publication number). Specifically, Patent search gives the user the ability to perform patent searches by entering queries manually in the dedicated box. In comparison, the tab concerning the Publication number option, provides the possibility to search by publication number one or several patents. Furthermore, for more experienced users there is the Expert option, which allows to apply and create custom queries. In order to develop the study of patent data, this elaboration will use the Fielded version of this patent search tool.

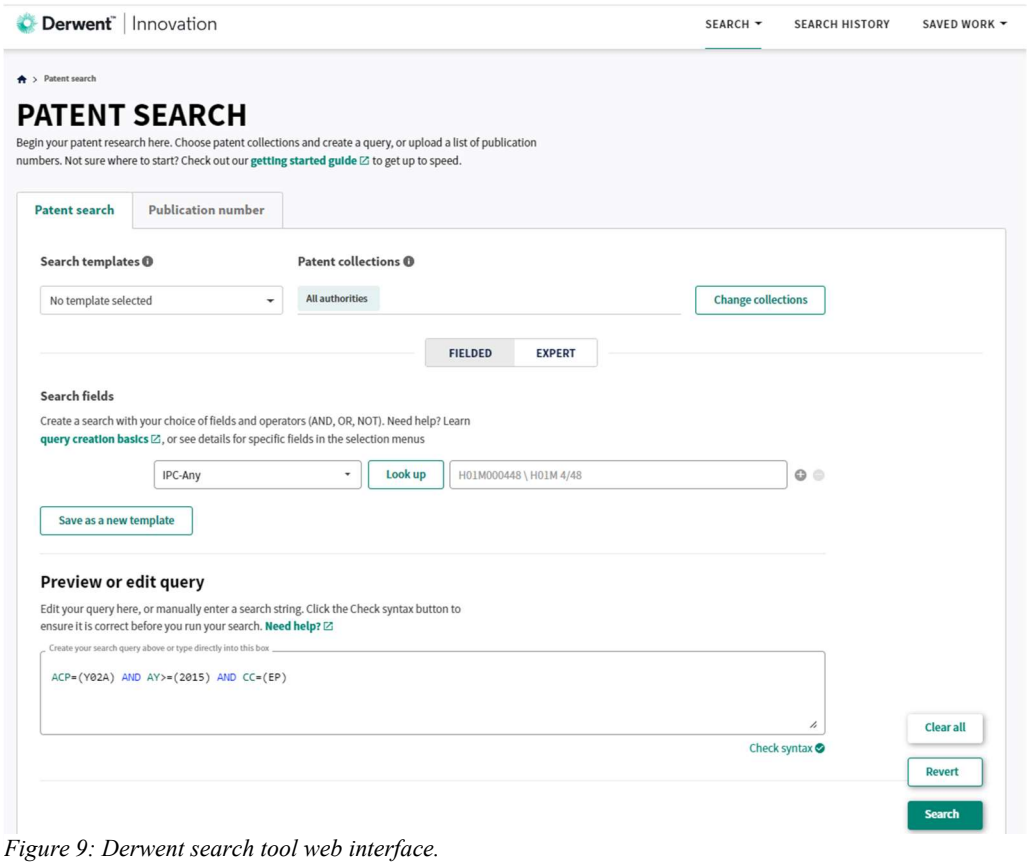

Figure 9: Derwent search tool web interface.

Source: https://www.derwentinnovation.com/login/

[27] https://clarivate.com/products/ip-intelligence/ip-intelligence-ip-data-and-apis/derwent-world-patents-index/

Finally, identified through a search the patents, Derwent provides the possibility of either saving the query in the search history or performing a massive download of the detected results, with a maximum 30 thousand patents per single download.

3.2 Identifying green innovations

The creation of queries is necessary to extrapolate from the Derwent database the study samples on which an analysis will be performed in the following chapter. To create queries, it is first necessary to figure out which patent families of interest pertain to innovations in the green field.

There are several classifications in literature to identify environmental innovations, and these are split between official classifications, compiled by international organizations, such as the WIPO IPC Green Inventory and Y-Tag EPO, and others made by researchers and academics, who have developed their own classification during their own research activities. In particular, the WIPO IPC Green Inventory classification will be of great help in writing this thesis project, since its main goal is to try to collect all green technologies in one place. Jointly with the WIPO IPC Green Inventory we are also going to use the Y-TAG EPO classification, that is used to identify patents related to climate change mitigation technologies.

After topic-based identification of the different green patent families, in paragraph 3.3, the information related to the definition of search criteria within the database will be elucidated, through the structuring of appropriate inputs to arrive at the extraction of databases related to patents issued in the green field.

3.2.1 IPC Green Inventory - WIPO

The WIPO IPC Green Inventory[28] was introduced on the 16th of September 2010, in this classification, green patents are identified based on the World Intellectual Property Organization (WIPO) International Patent Classification (IPC) system.

[28] https://www.wipo.int/classifications/ipc/green-inventory/home

The IPC Green Inventory, is an online repository, developed by the IPC Expert Committee, whose purpose is to identify and facilitate the retrieval of information on environmental patents, according to the United Nations Framework Convention on Climate Change (UNFCCC). To accomplish this goal, a comprehensive list of IPC codes is provided to identify green patents in different technology domains.

The classification includes all IPC classes that are associated with environmentally friendly technologies in different fields. Specifically, it includes seven technology areas related to the IPC codes, these several areas can be seen in the Table 1 below, to see the sub-topics in further detail related to the respective IPC codes see Appendix 1.

Table 1: IPC Green Inventory (WIPO) classification scheme by topic.

TOPIC	SUB-TOPICS
ALTERNATIVE ENERGY PRODUCTION	❖ BIO-FUELS ❖ FROM GENETICALLY ENGINEERED ORGANISMS ❖ INTEGRATED GASIFICATION COMBINED CYCLE (IGCC) ❖ FUEL CELLS ❖ PYROLYSIS OR GASIFICATION OF BIOMASS ❖ HARNESSING ENERGY FROM MANMADE WASTE ❖ HYDRO ENERGY ❖ OCEAN THERMAL ENERGY CONVERSION (OTEC) ❖ WIND ENERGY ❖ SOLAR ENERGY ❖ GEOTHERMAL ENERGY ❖ OTHER PRODUCTION OR USE OF HEAT, NOT DERIVED FROM COMBUSTION, E.G. NATURAL HEAT ❖ USING WASTE HEAT ❖ DEVICES FOR PRODUCING MECHANICAL POWER FROM MUSCLE ENERGY.
TRANSPORTATION	❖ VEHICLES IN GENERAL ❖ VEHICLES OTHER THAN RAIL VEHICLES ❖ RAIL VEHICLES ❖ MARINE VESSEL PROPULSION ❖ COSMONAUTIC VEHICLES USING SOLAR ENERGY
ENERGY CONSERVATION	❖ STORAGE OF ELECTRICAL ENERGY ❖ POWER SUPPLY CIRCUITRY ❖ MEASUREMENT OF ELECTRICITY CONSUMPTION ❖ STORAGE OF THERMAL ENERGY ❖ LOW ENERGY LIGHTING ❖ THERMAL BUILDING INSULATION ❖ RECOVERING MECHANICAL ENERGY
WASTE MANAGEMENT	❖ WASTE DISPOSAL ❖ TREATMENT OF WASTE ❖ CONSUMINGWASTE BY COMBUSTION ❖ REUSE OF WASTE MATERIALS ❖ POLLUTION CONTROL

AGRICULTURE/ FORESTRY	❖ FORESTRY TECHNIQUES ❖ ALTERNATIVE IRRIGATION TECHNIQUES ❖ PESTICIDE ALTERNATIVES ❖ SOIL IMPROVEMENT
ADMINISTRATIVE, REGULATORY OR DESIGN ASPECTS	❖ COMMUTING (E.G. HOV, TELEWORKING) ❖ CARBON/EMISSIONS TRADING (E.G. POLLUTION CREDITS) ❖ STATIC STRUCTURE DESIGN
NUCLEAR POWER GENERATION	❖ NUCLEAR ENGINEERING ❖ GAS TURBINE POWER PLANTS USING HEAT SOURCE OF NUCLEAR ORIGIN

3.2.2 Y-TAG - EPO

The European Patent Office (EPO) has introduced, since the 1st of January 2013, the Y02 - Y04S tagging scheme[29], a dedicated coding scheme for all patent documents related to Climate Change Mitigation Technologies (CCMTs).

Over the years this classification has been steadily expanded and currently has the composition shown in the Table 2. It is important to note that this classification also allows people without expertise on patents to search for technologies relating specifically to climate change in an easier way.

In addition, a Y04S scheme, a spin-off of Y02, has also been created for the classification of smart grids.

Table 2: Y02-Y04S classification scheme for environmental mitigation technologies (CCMTs).

Source: https://www.epo.org/news-events/in-focus/classification/classification/updatesYO2andY04S.html

SECTION	TITLE
Y02A	ADAPTATION TO CLIMATE CHANGE
Y02B	CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS, INCLUDING HOUSING AND ELECTRICAL APPLIANCES OR RELATED END-USER APPLICATIONS
Y02C	CAPTURE, STORAGE, SEQUESTRATION, OR DISPOSAL OF GREENHOUSE GASES
Y02D	ICT THAT AIMS TO REDUCE ITS OWN ENERGY CONSUMPTION
Y02E	CLIMATE CHANGE MITIGATION TECHNOLOGIES IN POWER GENERATION, TRANSMISSION AND DISTRIBUTION

[29] https://www.epo.org/news-events/in-focus/classification/classification/updatesYO2andY04S.html

Y02P	CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR MANUFACTURING OF GOODS
Y02T	TRANSPORTATION-RELATED CLIMATE CHANGE MITIGATION TECHNOLOGIES
Y02W	CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO WASTEWATER TREATMENT OR WASTE MANAGEMENT
Y04S	SMART GRID TECHNOLOGIES

More specifically, from the above Table 2, it is noticeable that group Y02 covers the different technical areas, in which climate change mitigation can be identified (to view the classification in further detail, consult Appendix 2) and is divided into the following subclasses[30]:

- Y02A is concerned with climate adaptation technologies, so for example technologies to adapt or protect infrastructure or its operation, adaptation technologies in agriculture or production, in the protection of human health (e.g., against extreme weather conditions) and also include technologies that indirectly contribute to climate change adaptation;
- Y02B is related to buildings. Through this subclass one can find patent documents related to the integration of renewable energy sources such as, for example, tiny wind turbines or solar panels in buildings (Y02B10), energy-efficient lighting technologies such as LED lights (Y02B20), etc.;
- Y02C relating to all greenhouse gas capture, storage and disposal technologies;
- Y02E related to energy, which includes in addition to renewable energy sources, nuclear-related technologies, more specifically under code Y02E30;
- Y02D includes all the climate change mitigation technologies in information and communication technologies [ICT], i.e. information and communication technologies aiming at the reduction of their own energy use;
- Y02P concerning industry and agriculture. This subclass ranges from primary industry that gathers and produces raw materials for manufacturing, which includes agriculture, all the way to secondary industry that makes products consumed by individuals;

[30] Angelucci S., Hurtado-Albir F. J., Volpe A., *Supporting global initiatives on climate change: The EPO's "Y02-Y04S" tagging scheme*, World Patent Information, 2017.

- Y02T pertaining to rail, aviation, maritime transportation and improved internal combustion engine-based technologies;
- Y02W which is divided into two parts. One related to wastewater treatment and the second one is about waste management.

Y04S is a separate scheme, closely related to Y02, which was mentioned at the beginning of the subparagraph and is dedicated to smart grids. However, the latter will not be considered in our analysis.

3.3 Search query construction method

This paragraph will clarify the logic behind the construction of the patent search queries, which were applied to the Derwent database to obtain patent information in the field of green innovations, those will then be analyzed in the following chapter in order to achieve the ultimate goal of the thesis, that is, to fully analyze and understand the technological scenario related to these environmental technologies.

3.3.1 Preliminary analysis and keyword identification

One further aspect to be strongly considered in the patent search phase regarding the IPC Green Inventory classification (WIPO), turns out to be the search keywords, in fact, a mere search of only the IPC codes pertaining to the different classes would only lead to a very broad and not detailed search perimeter.

To be able to find the relevant keywords in the technology area under consideration, with the aim of refine the search scope on Derwent, the main features and terminologies used in the description of green technology were considered. In addition, keywords were also searched through the use of the free patent search engine PatentInspiration, after selecting the IPC codes of interest and examining the patent abstracts.

The analysis revealed the following keywords for the green sphere:

- Environment friendly;
- Renewable;
- Green energy;

- Energy savings;
- Ecological;
- Pollution.

These terms just mentioned were then entered with appropriate modifications on Derwent database to formulate an initial search query in order to understand whether the search path taken would bring correct outcomes, consistent with the technological field under analysis.

Cross-searching these keywords with IPC Green Inventory (WIPO) codes ensures specific and consistent results with the target technology field, while at the same time avoid including patents belonging to other technologies that respond to one or more of the selected keywords.

3.3.2 IPC Green Inventory Final Search Queries

To perform the analyses in Chapter 4, it is necessary to create a query for each group in the IPC Green Inventory (WIPO).

It is necessary, for the purpose of fully understanding the search queries used, to introduce a legend of the operators used by Derwent to perform database queries:

- IC = It indicates that the referenced keyword is an IPC code, hence it will be searched within the IPC fields of the database;
- OR = It is used where two terms are searched and one term or the other must be present somewhere in the same document;
- AND = it is employed to search for two terms that must both be present. This operator does not place any conditions on the position of the terms relative to each other, in fact, the terms must simply appear somewhere in the same document;
- ALL = It specifies that the referenced keyword should be searched in all text headings, so in both Title, Abstract, and Description (it is opted not to use TAB, which selects keywords only from the Title and Abstract, because after making an attempt it turns that the results obtained are too restrictive);
- * = The asterisk character represents zero or an unlimited number of characters. The asterisk can be used inside a word (e.g. environment* can be searched as environmental, environmentally and so on);

- NEARn = It is typically used to search for records containing the specified terms in any order. If it is followed by a numeric qualifier n, it searches records containing the specified terms within n words of each other, in any order. The value n specifies the number of searchable terms (minus one) allowed among the search terms;
- "" = Enclosing search terms in double quotes always searches for exactly those terms in that order and proximity;
- AY= stands for Application Year, this thesis will focus on more recent years, so we will take an AY>=2015;
- CC= Represents Country Code, this elaborate will concentrate on the European market, so we will set CC=EP.

The search query for the sixth group of the IPC Green Inventory (WIPO), namely "*Administrative, regulatory or design aspects*", is given below as an example:

IC=(G06Q OR G08G OR E04H000100) AND ALL=((environment* NEAR2 friend) OR renewable OR "green energy" OR (energy NEAR2 saving) OR ecolog* OR pollut*) AND AY>=(2015) AND CC=(EP)

In a similar way, the other queries for the other categories were created, to see them in detail, see Appendix 3. Therefore, each query was structured into four main selections. In the first one it is possible to find the IPC codes of the chosen category of IPC Green Inventory (WIPO) linked together using the logical OR operator, so that all patents belonging to at least one of these classes are obtained. Whereas, in the second section, the keywords chosen are requested using the OR operator, which means that the patents are required to contain in the title, abstract or description fields at least one of these keywords. In addition, the NEAR operator has been added between the words that make up some keywords, since it is required that the two words must be adjacent, because if not, the keyword would lose its meaning.

These first two sections just mentioned are connected through an AND operator, which ensures that the results meet both conditions described above. This provides a database that matches the identified keywords and at the same time also meets the condition that the patents under consideration belong to the IPC classes of the Green Inventory (WIPO).

And lastly, the third and fourth selections are respectively to choose an application year starting from 2015 to the present day and that the market chosen for patent extraction must be the European market.

3.3.3 Y02 Final Search Queries

Regarding the Y02 (EPO) classification, again a specific query will be created for each class, but unlike before, keywords will not be applied.

Below is given as an example the search query for group Y02A:

ACP=(Y02A) AND AY>=(2015) AND CC=(EP)

ACP indicates that the reference keyword is a CPC[31] code therefore it will be searched within the CPC fields of the Database. While, exactly as before the other two expressions linked with logical operator AND indicate that the focus is on the most recent years (2015 to the present day) and that the reference market is European.

The queries of the other categories belonging to Y02, can be seen in Appendix 4.

[31] The Cooperative Patent Classification (CPC) is an extension of the IPC and is administered jointly by EPO and the U.S. Patent and Trademark Office. It consists of nine sections, from A to H plus Y, that are in turn divided into classes, subclasses, groups and subgroups.

CHAPTER 4: Results analysis

Premised on the methodology used in gathering the data in the prior chapter, attention will now be focused, instead, on the part concerning the computational analyses conducted. In first instance, it is useful to evaluate the general results obtained, through the queries carried out previously, related to the technological fields that make up the two classifications examined, IPC Green Inventory (WIPO) and Y02 (EPO), from the point of view of the number of patents issued for each technological field. In this way, it will be easy to sense where there is more innovativeness.

Subsequently, once the general context has been outlined, then it will be possible to go into greater detail by analyzing two categories for the IPC Green Inventory classification and two groups from Y02, whose databases will be exported for examination with the ultimate goal of obtaining useful information on their technological scenario. To perform these analyses, Excel will be used, while some graphs, will be taken from those of Derwent, which are proposed in the analysis of the results.

4.1 Overview IPC Green Inventory and Y02

Once the different queries for each topic of both the IPC Green Inventory and the Y02 categories were made, the Derwent Innovation database was interrogated with these queries. In this way, for each different class of the two classifications, the corresponding numerical patent quantities were obtained.

Further to the display of the results obtained, in the following subsections a brief overview will be given regarding the market status of Transportation, Waste Management, Y02B, and Y02D, which are the categories chosen to conduct a more accurate analysis by exporting the relevant databases.

4.1.1 IPC Green Inventory (WIPO)

Regarding the first research[32] for the period 2015 to 2022 conducted for the classification codes belonging to the green inventory compiled by WIPO, comprising seven distinct categories, it can be seen that the latter led to the results visible in the Table 3 below. Examining the data obtained, it can be noticed that at the moment the category for which the more green innovations occur is Alternative Energy Production, followed by the one concerning Waste Management immediately after.

Table 3: Patent search on Derwent Innovation for IPC Green Inventory (WIPO) classification from 2015 to 2022.

TOPIC	NUMBER OF PATENTS
ALTERNATIVE ENERGY PRODUCTION	7.607
WASTE MANAGEMENT	4.850
ENERGY CONSERVATION	3.945
ADMINISTRATIVE, REGULATORY OR DESIGN ASPECTS	2.330
TRANSPORTATION	1.640
AGRICULTURE/FORESTRY	838
NUCLEAR POWER GENERATION	209

In specific, by looking at Waste Management, which was shown to be the second category with the most tendency toward innovation, an overview of the relative "state of the market" and its segmentation is provided in the Figure 10. From the chart, it is clear that in the time frame from 2019 to 2022, the top 3 technology areas to stand out in terms of innovation within this topic are:

1. Wastewater, desalination, reverse osmosis, purification;
2. Separation or filtration of gas, carbon dioxide;
3. Catalyst, hydrocarbon, dehydrogenation, zeolite.

These three most innovative technology fields are accounted for 58% of the total results for these years in exam. Currently, the top three firms that are developing and innovating on these technologies just listed are SCANIA CV

[32] This research on IPC Green Inventory codes was conducted on the date 07/06/2022 on Derwent Innovation

AB, CENTRE NAT RECH SCIENT, and VOLKSWAGEN AG, which together represent for 80% of all records in the entire result set.

Figure 10: Technologies developed in Waste Management from 2019 to 2022.

Source: Derwent Innovation

On the other hand, glancing at the areas of technology with the most innovation in the last four years regarding the topic of Transportation (see Figure 11) highlights the top three in the ranking as:

1. Charging, wireless power, battery, direct current, voltage;
2. Electric vehicle, energy storage;
3. Secondary battery, fuel cell, current collector, cathode active.

In their totality, these technology domains account for 54 percent of the patents published from 2019 to 2022, and LG CHEMICAL LTD, ALSTOM TRANSP TECH and SIEMENS MOBILITY GMBH are the largest firms investing in green innovations on these topics.

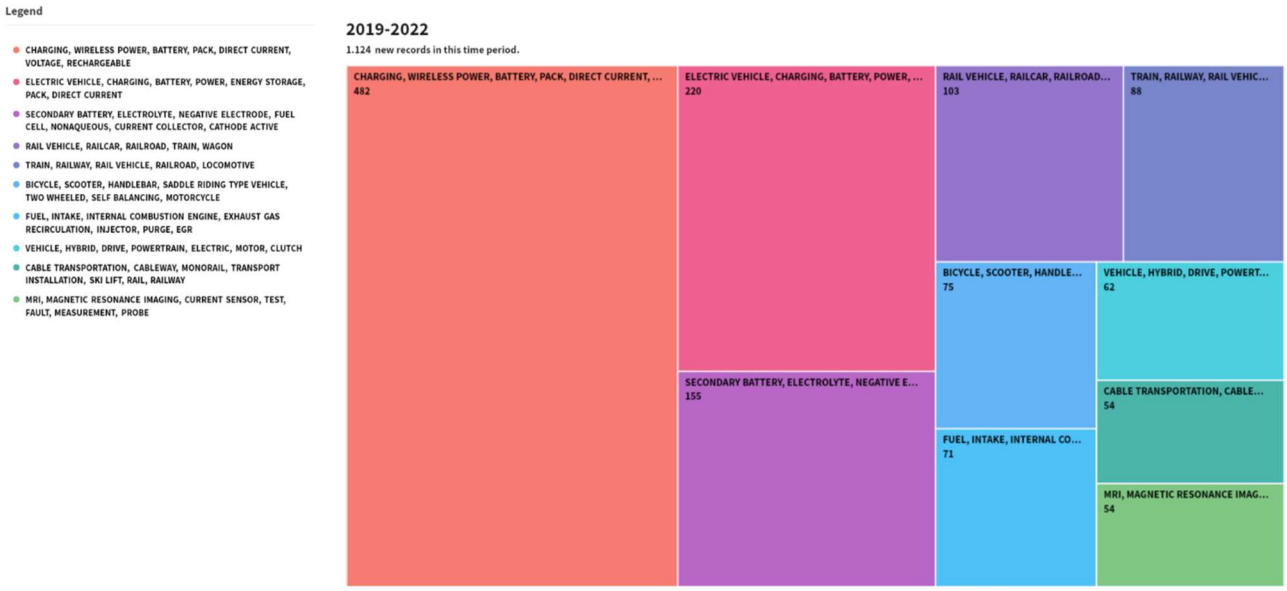

Figure 11: Technologies developed in Transportation from 2019 to 2022.

Source: Derwent Innovation

4.1.2 Y02 (EPO)

Regarding the Y02 classification, the patent search[33] carried out for the time frame from 2015 to 2022 using the different classification codes related to climate change technologies (CCMTs) shows the results presented in the Table 4. In this case, Y02E related to CCMTs for power distribution and generation turns out to be the biggest innovator in the Y02 classification, followed in turn by Y02T and Y02P.

In the next paragraphs for groups Y02B and Y02D, which are related to green technologies respectively in the construction and ICT sectors that have as their main goal to reduce their energy consumption, a more specific analysis will be made.

[33] This research on Y02 classification was conducted on the date 07/06/2022 on Derwent Innovation

Table 4: Patent search on Derwent Innovation for Y02 (EPO) classification from 2015 to 2022.

GROUP	NUMBER OF PATENTS
Y02E CLIMATE CHANGE MITIGATION TECHNOLOGIES IN POWER GENERATION, TRANSMISSION AND DISTRIBUTION	66.395
Y02T TRANSPORTATION-RELATED CLIMATE CHANGE MITIGATION TECHNOLOGIES	39.187
Y02P CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR MANUFACTURING OF GOODS	36.400
Y02B CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS, INCLUDING HOUSING AND ELECTRICAL APPLIANCES OR RELATED END-USER APPLICATIONS	15.816
Y02A TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE	12.827
Y02D ICT THAT AIMS TO REDUCE ITS OWN ENERGY CONSUMPTION	12.097
Y02W CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO WASTEWATER TREATMENT OR WASTE MANAGEMENT	5.482
Y02C CAPTURE, STORAGE, SEQUESTRATION, OR DISPOSAL OF GREENHOUSE GASES	1.981

The following discussion, for both Y02B and Y02D, as previously for the Waste Management and Transportation themes, will consider the technology areas in each group on which innovators have focused most on recent years.

Starting with the Y02B group, from the Figure 12 which follows, is provided the current market condition. The first three most innovative technology domains of the 2019-2022 window, which account for 45% of the total patents analyzed in that time frame, in this case turn out to be:

1. Lighting, heating, cooking, induction;
2. Power converter, direct current, inverter, voltage, switch, flyback, circuit;
3. Charging, wireless power, battery.

MITSUBISHI ELECTRIC CORP, LG ELECTRONICS INC, and SIGNIFY HOLDING BV represent the three companies that are putting the most investment into innovation for these just mentioned technologies, and together they express 80 percent of all records in the entire set of results (from 2019 to 2022).

Figure 12: Technologies developed in Y02B from 2019 to 2022.

Source: Derwent Innovation

Turning to the analysis of the market status of Y02D and its segmentation. It is clear from the Figure 13 that over the past 4 years the leading 3 technology areas to stand out in terms of innovation within this topic are:

1. User equipment, wireless communication, uplink, indicaton information, network;
2. Computing, transitory, touch, information processing, virtual, management;
3. Blockchain, cloud, sending.

These three most innovative technology fields are accounted for 95% of the total results in these 4 years in exam. At the moment, the top 3 companies

that are developing and innovating on these technologies just listed are HUAWEI TECH CO LTD, QUALCOMM INC and SAMSUNG ELECTRONICS CO LTD.

Figure 13: Technologies developed in Y02D from 2019 to 2022.

Source: Derwent Innovation

4.2 Data extraction from Derwent Innovation

From Derwent Innovation platform, a total of four databases were exported and subsequently analyzed. The first two of these belong to the IPC Green Inventory (that are, Transportation and Waste management) and the remaining two belong to the Y02 classification (which are, Y02B and Y02D).

At each export, the following data were chosen to be stored as columns of the extracted dataset:

- Publication number, this is the unique code associated with the patent;
- Publication country code, corresponding to a code that uniquely represents the country of the patent document;
- Assignee- Standardized, which is the name of the inventor;
- Optimized Assignee, that is, the name of the optimized inventor, if referable to companies or other corporations, this is the prevailing applicant compared to the possible multiplicity of applicants;

- Application year, representing the year of the patent application date, as well as the year from which patent protection applies to the patented invention;
- Count of citing patents, also referred to as "forward citations," these represent the number of citations of patents filed later than the patent under consideration, useful in calculating the importance of the patent.

Having now had a clear view of the parameters useful for carrying out the analyses, the following paragraphs will analyze the four databases specifically, both in terms of publication trends over the years and with regard to the major players in the industry.

4.3 Publication Trend

The first information of great interest to implement an analysis of the technological scenario turns out to be the trend of publications over the years, in fact, this trend can be considered as a good estimate of the interest of companies and with a more overall look of the markets. In this first level of investigation for each database all the corresponding patents, obtained through the use of queries, will be considered with the aim of understanding which were the years of major growth.

The Publication Trend appears to be essential for showing publication trends over the years. The set of variables used in the graph are: on the y-axis the Publication Number and on the x-axis the Publication Year, which is the year of publication of patents after their filing (usually equivalent to 18 months).

It is significant to note that in the graphs analyzed, only patent data obtained up to 2021 will be taken into account, as the 2022 year is still in progress and would not be correct to employ in the analysis, as it would show reversals of trends which may not be strictly true.

4.3.1 Transportation

The first analysis regarding the Transportation category, as mentioned earlier, chose to take into account, for the reasons explained above, patents published in the time frame from 2015 to 2021, which represent 90.6 percent of the patents identified in the dataset.

More specifically, it can be seen from Figure 14 how the trend over the years is growing. From that it emerges that the green market regarding innovations in transportation is experiencing strong increase. In particular, it is noticeable that initially a very vigorous uptrend is present, but then between 2018 and 2019 it tends to become more moderate, only to resume the rise with renewed vigor and reach a peak of 385 patents in 2021.

However, the growth goes from a value of 24 related to the year 2015 until reaching a total of 385 for the year 2021, sixteen times as much as that found 6 years earlier, symbolizing the fact that investment in this category has increased over the years.

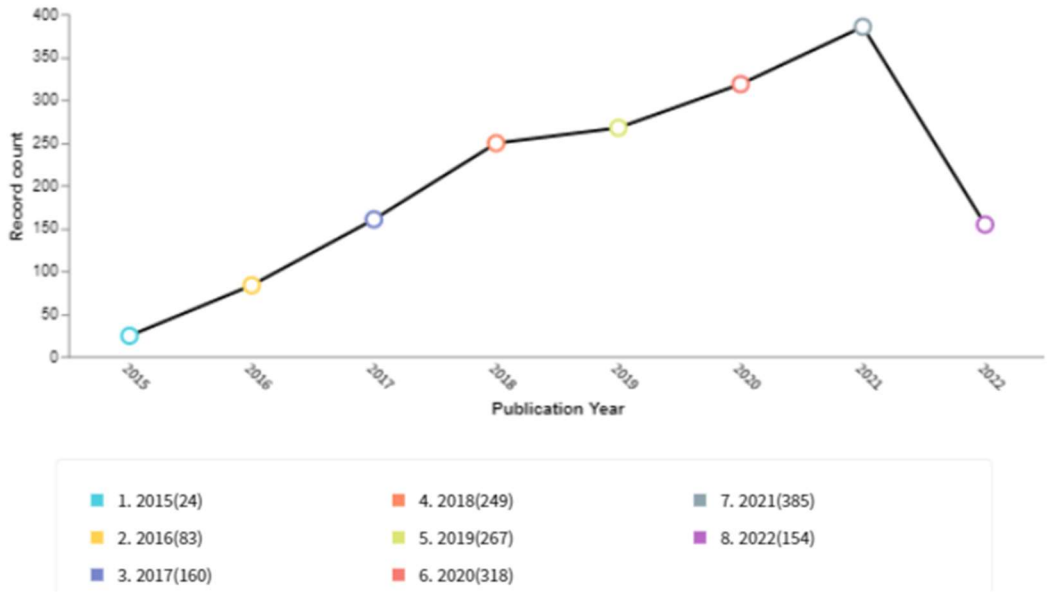

Figure 14: Patent publishing trends in Transportation from 2015 to 2022.

Source: Derwent Innovation

4.3.2 Waste Management

Similar to before, for the topic inherent to Waste Management the analysis will also take into account patents published in the seven-year time frame from 2015 to 2021, in this case equivalent to 91.3 percent of the 4.850 patents identified by the query used.

Analyzing the Figure 15 it is seen that there is a steady growth over the years since 2015, but this seems to stabilize at just over 1,000 patents in the years 2020 and 2021. In any case, from 2015 to 2021 there is an increase from a

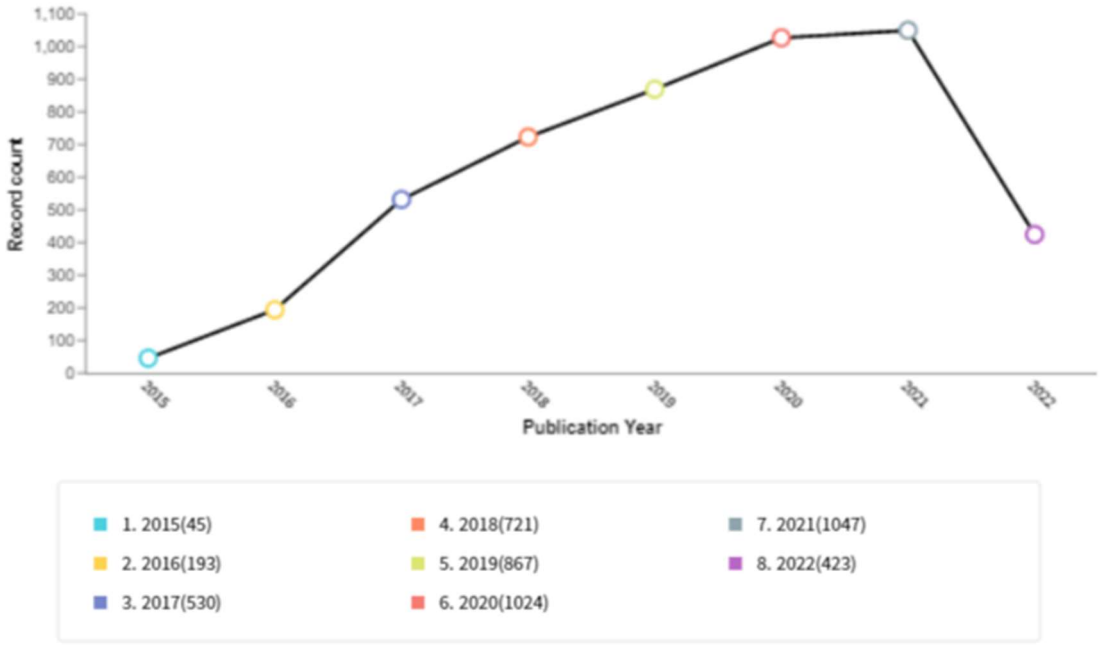

Figure 15: Patent publishing trends in Waste Management from 2015 to 2022.

Source: Derwent Innovation

meager amount of 45 published patents to more than a thousand, this is an indicator that innovations in this area have increased in recent years and that Waste Management is an attractive field for the market.

4.3.3 Y02B

The analysis will be proceeded for Y02B in the exact same way as previously used for the two topics of the IPC Green Inventory, so the time spectrum used here will also be from 2015 to 2021, which means that 94.5 percent of the 15,816 patents identified in the chosen database will be considered for this group.

It is evident from the Figure 16 that starting from 2015, there is an increasing trend over the years up to 2020 where a peak of 3285 patents is reached, and then it slightly declines in 2021 reaching the publication of 3261 patents. However, it must be kept in mind that patents are uploaded to online databases, such as Derwent Innovation's, a few months after their publication

so the last couple of most recent years may be underestimated; therefore, it is not guaranteed that the patent trend is really reversing.

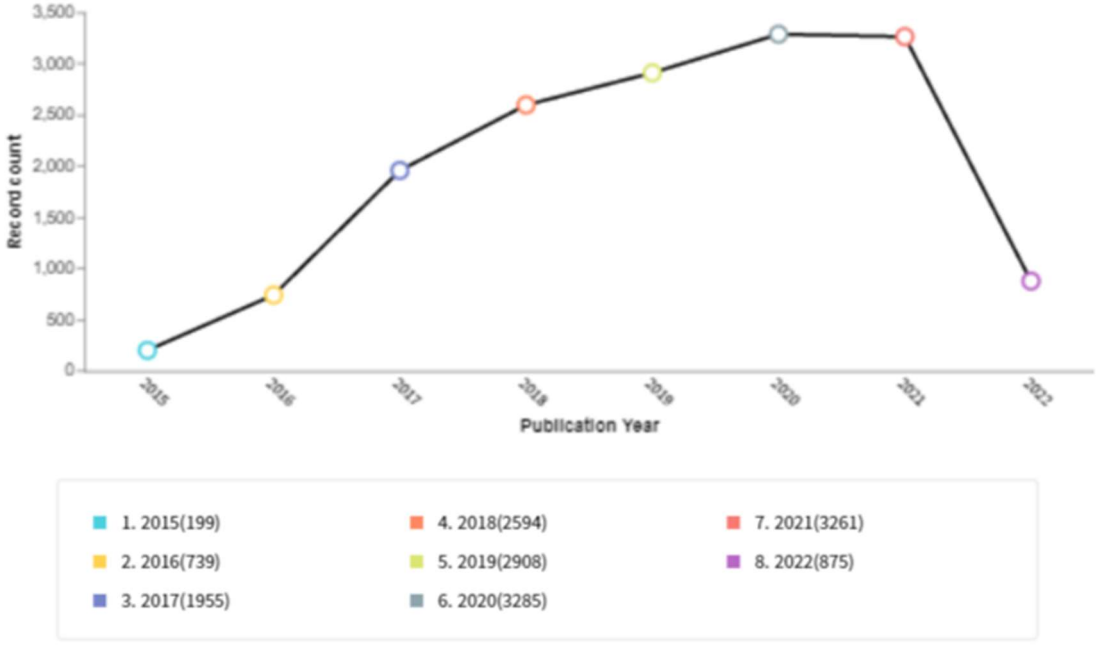

Figure 16: Patent publishing trends in Y02B from 2015 to 2022.

Source: Derwent Innovation

4.3.4 Y02D

Finally, with regard to the Y02D group, it is noted that considering the number of patents included in the 2015-2021 time frame, these are equivalent to 90.9 percent of the 12.097 patents identified by the query carried out in the previous chapter.

Once again, an upward trend can be seen from the Figure 17 as the years flow, which does not yet seem to have reached its own peak, but is still continuing to rise, which suggests that investment in this Y02D group is keeping on increasing over the years. That is confirmed by the staggering growth made from 2015 in which there were about 90 published patents to 2021 in which there are 2620, much more than double.

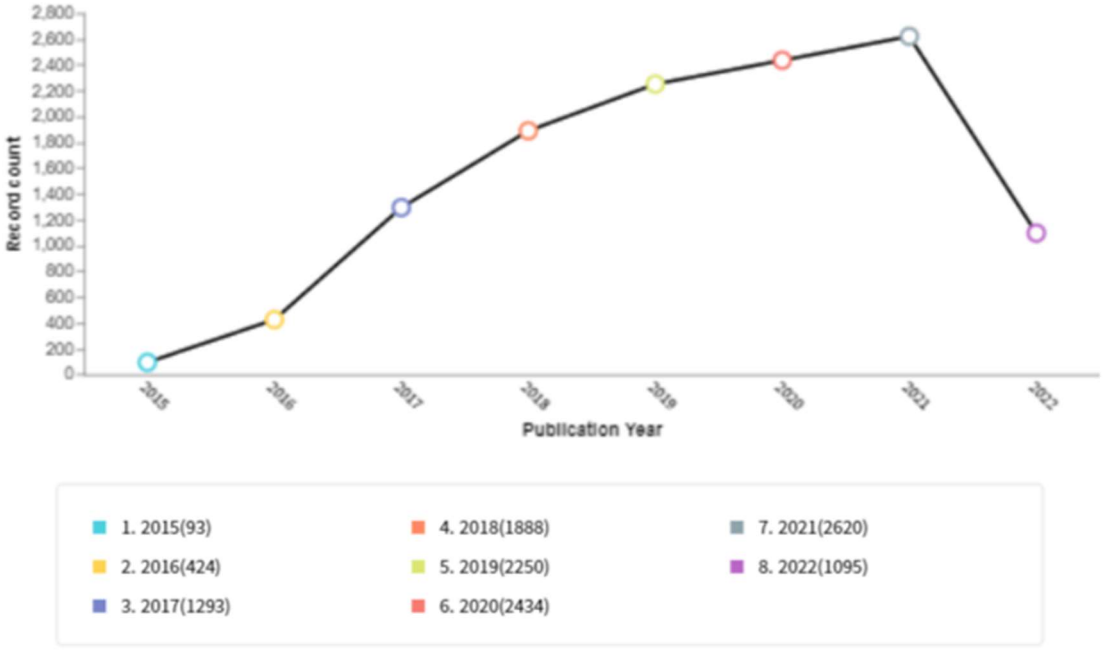

Figure 17: Patent publishing trends in Y02D from 2015 to 2022.

Source: Derwent Innovation

4.4 The 20 major players in publishing patents

The method for selecting companies on Derwent Innovation, as mentioned in Section 4.2, is the one of the Optimized Assignee, which means that the optimized assignee provides as an output a single result, which is the result of a standardization of the organization that applied for the patent. In fact, different patent documents may use different combinations of company names or abbreviations, but through the employment of the Optimized Assignee these multiple name variations are reduced to a single standardized name. After exporting the four databases to Excel, however, further standardization was performed to improve the accuracy of the data obtained even more.

It is important to note that in the analyses regarding the companies that will follow in the subsequent subparagraphs, it has been decided that for each of the four chosen databases only the 20 players with the most published patents will be represented.

4.4.1 Transportation

With regard to the Transportation topic, the leading 20 players, as shown in Figure 18, in publishing patents in this area represent 26 percent of the entire dataset obtained, corresponding to a quota of 421 patents out of the 1.640 extracted through the query.

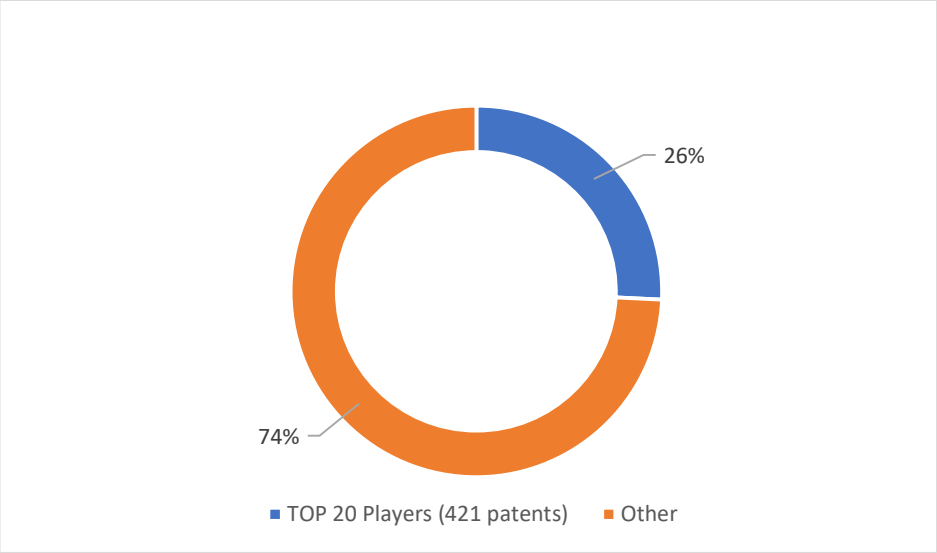

Figure 18: Share of the top twenty companies (26%) in relation to the total companies of the dataset obtained for Transportation.

More specifically, Figure 19, is provided to see in detail which companies stand out as major publishers in the green transportation sector. First among them is SIEMENS MOBILITY, a leading German company in sustainable and efficient transportation solutions, which ranks first with 48 patents. Right behind, in second place with the same amount of published patents as SIEMENS, is LG CHEM LTD. a chemical company. While, in third place can be found ALSTOM TRANSPORT SA, a French industrial group active in the construction of trains and rail infrastructure.

Still in the area of rail transportation, three other companies can be discerned: BOMBARDIER TRANSPORTATION BUSINESS in sixth place; CRRC CORPORATION, in eighth place, which is the world's largest manufacturer of rolling stock; and, finally, HITACHI LTD, which also manufactures earthmoving equipment in twelfth place. In addition, there is also SNCF SOC NAT CHEMINS DE FER, a French public railway company in twentieth place. In seventeenth position, there is HITACHI CONSTRUCTION MACHINERY CO LTD, a company focused on building construction

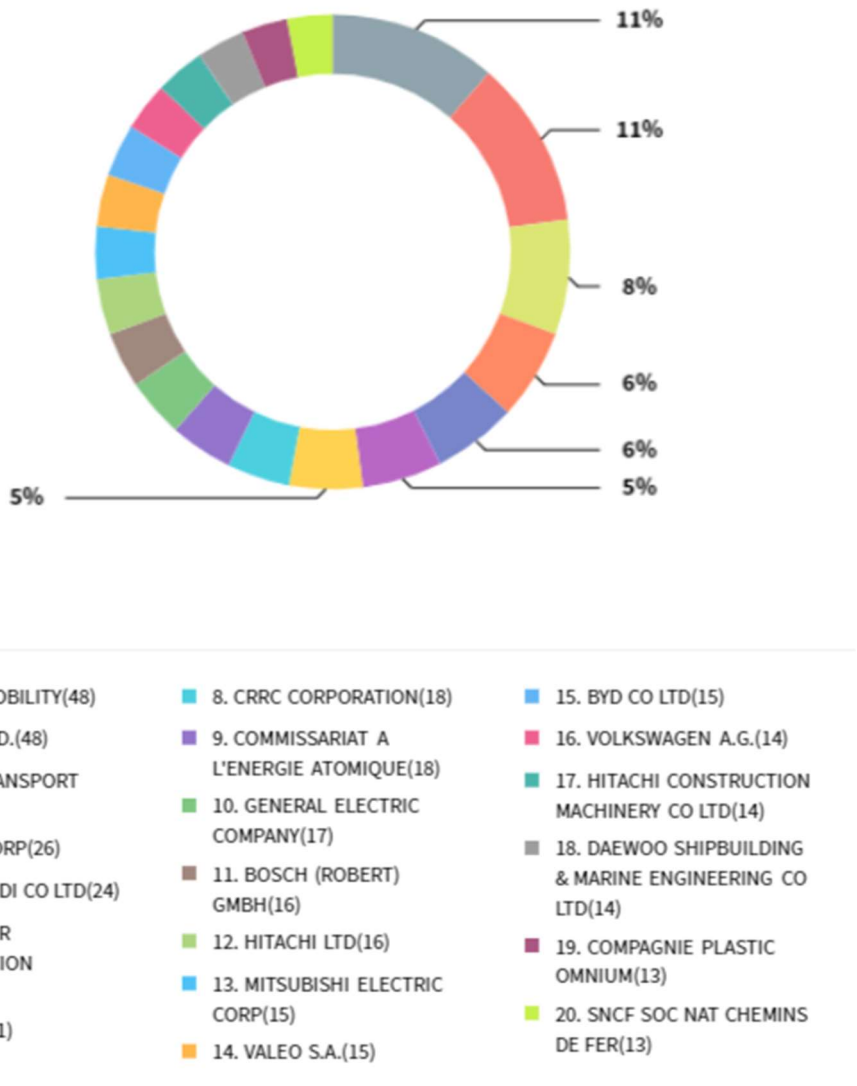

Figure 19: Percentage shares related to the number of patents per company based on the top 20 companies for Transportation.

Source: Derwent Innovation

machinery, and in seventh and sixteenth position, respectively, two well-known brands in automobile manufacturing can be seen, such as: VOLVO AB and VOLKSWAGEN A.G.. Furthermore, also concerning the automotive sphere there is BYD CO LTD, a manufacturer of automobiles, batteries for electric vehicles and electric bicycles and GENERAL ELECTRIC COMPANY, which manufactures both motors and electric machines It is useful to remind that as stated in sub-section 4.1.1 electric vehicles are second in the rankings in the most developed technological spheres in the last 4 years, so companies that deal with this technology are more likely to be biased toward innovation because they possess the know-

how. Then there is DAEWOO SHIPBUILDING & MARINE ENGINEERING CO LTD, a renowned Korean shipbuilder. In eleventh and fourteenth positions, one can find BOSCH GMBH and VALEO S.A, two major manufacturers of automobile components, while, in nineteenth position is COMPAGNIE PLASTIC OMNIUM, a company active in intelligent body systems and automotive module assembly. In addition, as many as three battery and electronic component manufacturing companies are also discovered, namely, TOSHIBA CORP (26 patents), SAMSUNG SDI CO LTD (24 patents) and MITSUBISHI ELECTRIC CORP (15 patents). It is important to remember what was seen in section 4.1.1, which is that batteries are first technology domain by innovation of the time frame from 2015 to 2022, so the companies just listed could be among the main carriers of innovation for this area. Finally, in ninth position comes COMMISSARIAT A L'ENERGIE ATOMIQUE, a French research center.

Considering now the sectors of the companies just listed, it can be seen that most of the firms are involved in the electronics sector, as many as seven: LG CHEM LTD., TOSHIBA CORP, SAMSUNG SDI CO LTD, BOSCH GMBH, HITACHI LTD, MITSUBISHI ELECTRIC CORP and BYD CO LTD. Second in terms of importance is the transportation and railway engineering sector, comprising six companies: SIEMENS MOBILITY, ALSTOM TRANSPORT SA, BOMBARDIER TRANSPORTATION BUSINESS, CRRC CORPORATION, HITACHI CONSTRUCTION MACHINERY CO LTD and SNCF SOC NAT CHEMINS DE FER. Third in size is the automotive sector with a quota of four firms: VOLVO AB, VALEO S.A., VOLKSWAGEN A.G. and COMPAGNIE PLASTIC OMNIUM. There is also GENERAL ELECTRIC COMPANY, a conglomerate operating in both the automotive and electronics sectors. The two remaining companies represent two different sectors: DAEWOO SHIPBUILDING & MARINE ENGINEERING CO LTD for the shipbuilding sector and COMMISSARIAT A L'ENERGIE ATOMIQUE for the atomic and renewable energy sector.

4.4.2 Waste Management

Shifting the focus now to the group related to Waste Management, Figure 20 that follows shows the percentage of patents obtained by the biggest 20 companies publishing patents in this topic, which equals to 12 percent compared to the entire dataset of 4.850 patents.

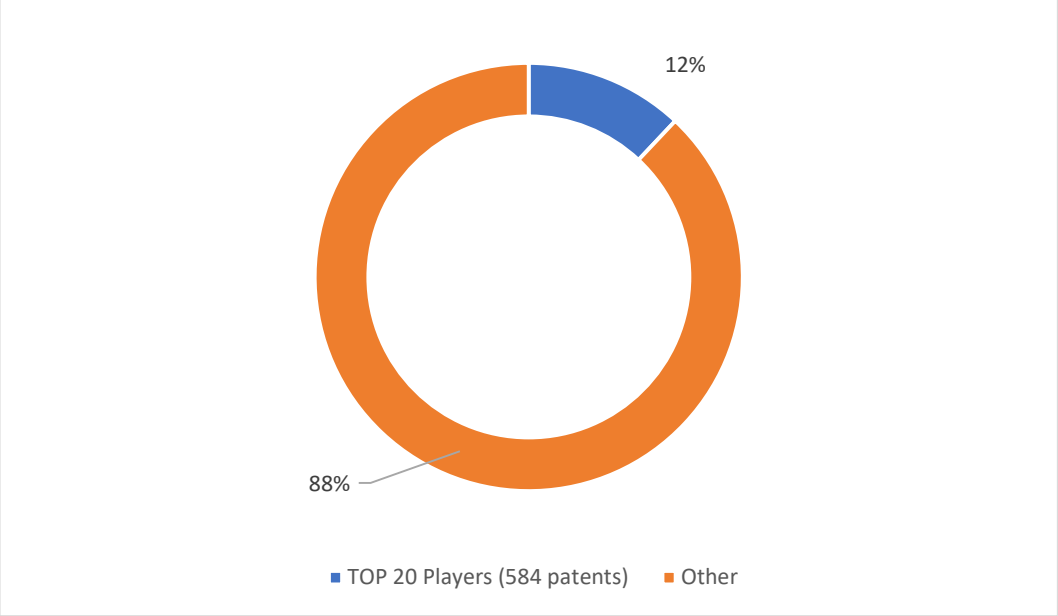

Figure 20: Share of the top twenty companies (12%) in relation to the total companies of the dataset obtained for Waste Management.

To get further focus on exactly which are precisely these top 20 players take a look at the Figure 21. Where ranked first and second are two firms with both 46 published patents, namely: SCANIA AB and SUEZ ENVIRONNEMENT CO SA. The first mentioned company is a Swedish manufacturer of industrial vehicles, while, the second is a global group in the field of water and waste management. Only one patent away is VEOLIA ENVIRONNEMENT, a French multinational, which in the same way as SUEZ ENVIRONNEMENT, is involved in water and waste management and energy services. On this branch of wastewater treatment solution, which it is recalled as reported previously in subsection 4.1.1 is the first to stand out among the Waste Management technology innovative fields in the last four years, there is also the company EVOQUA WATER TECHNOLOGIES LLC in sixteenth place.

In addition, within this classification there are also two automotive companies (i.e., PSA AUTOMOBILES SA in fourth place and VOLKSWAGEN A.G. immediately following in fifth place), a German truck manufacturer (MAN SE) and a heavy equipment manufacturer such as DOOSAN HOLDING. As well, there are two research centers COMMISSARIAT A L'ENERGIE ATOMIQUE (21 patents) and CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIC (37 patents) and three

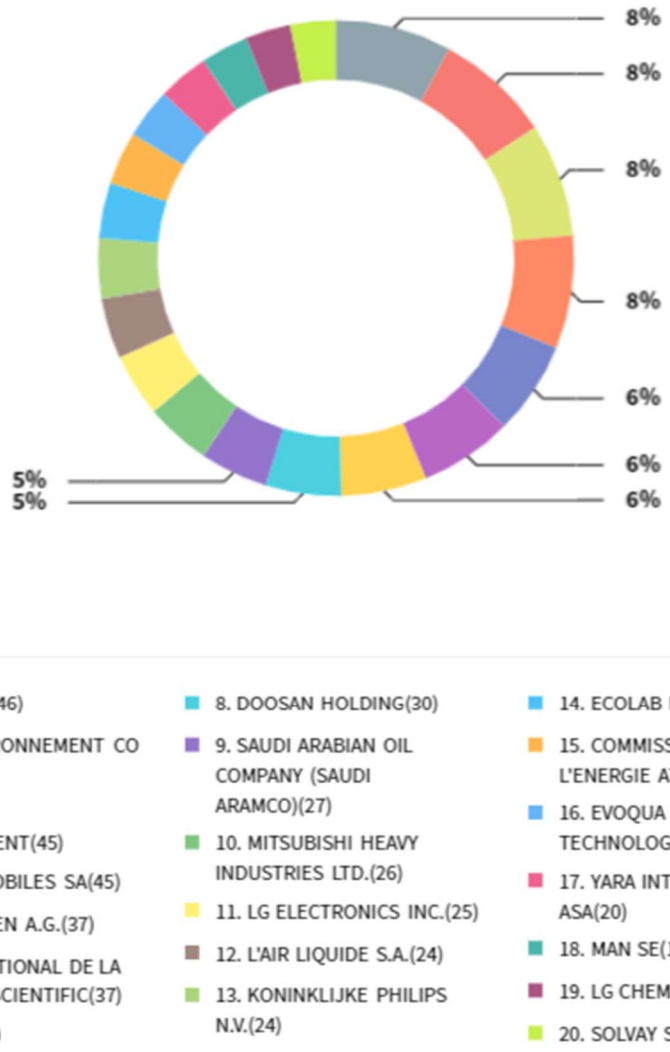

Figure 21: Percentage shares related to the number of patents per company based on the top 20 companies for Waste Management.

Source: Derwent Innovation

chemical companies LG CHEM LTD. (18 patents), BASF SE (34 patents) and SOLVAY S.A. in last place in the top 20 players with 18 published patents. Furthermore, there are: AIR LIQUIDE S.A., a company for the production of gas in industrial plants; SAUDI ARABIAN OIL COMPANY

and MITSUBISHI HEAVY INDUSTRIES LTD, the latter of which is especially dedicated to the field of wind energy. Finally, in order of numbers of published patents are also: LG ELECTRONICS INC. (25 patents) widely known for manufacturing electronic equipment and cell phones; KONINKLIJKE PHILIPS N.V. (24 patents), a major leader in the health care industry; ECOLAB INC. (22 patents), which sells cleaning and pest control products; and finally YARA INTERNATIONAL ASA (20 patents), a Norwegian manufacturer of fertilizers derived from nitrogen-based chemical processes.

With regard to the sectors of the companies listed previously, it can be seen that the two largest sectors in terms of importance are the waste disposal treatment services sector (SUEZ ENVIRONNEMENT CO SA, VEOLIA ENVIRONNEMENT, ECOLAB INC. and EVOQUA WATER TECHNOLOGIES LLC) and the chemical sector (BASF SA, L'AIR LIQUIDE S.A, YARA INTERNATIONAL ASA and SOLVAY S.A.).In third place in terms of importance are the energy sector (CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIC, SAUDI ARABIAN OIL COMPANY and COMMISSARIAT A L'ENERGIE ATOMIQUE) and the electronic sector (LG ELECTRONICS INC., KONINKLIJKE PHILIPS and LG CHEM LTD.). In comparison, in fourth place there are three different sectors: engineering (SCANIA AB and MAN), construction equipment (DOOSAN HOLDING and MITSUBISHI HEAVY INDUSTRIES LTD.) and, finally, the automotive sector (PSA AUTOMOBILES SA and VOLKSWAGEN A.G.).

4.4.3 Y02B

The focus will now be on the Y02B group of the Y02 classification, which covers, as seen in the preceding chapter, technologies related to buildings, including housing and appliances or related end-user applications. In this case, the twenty most prominent players in patent publication in the field correspond to 28.5 percent (Figure 22) of the database obtained through the query carried out in the previous chapter, which had led to the identification of a total of 15.816 patents.

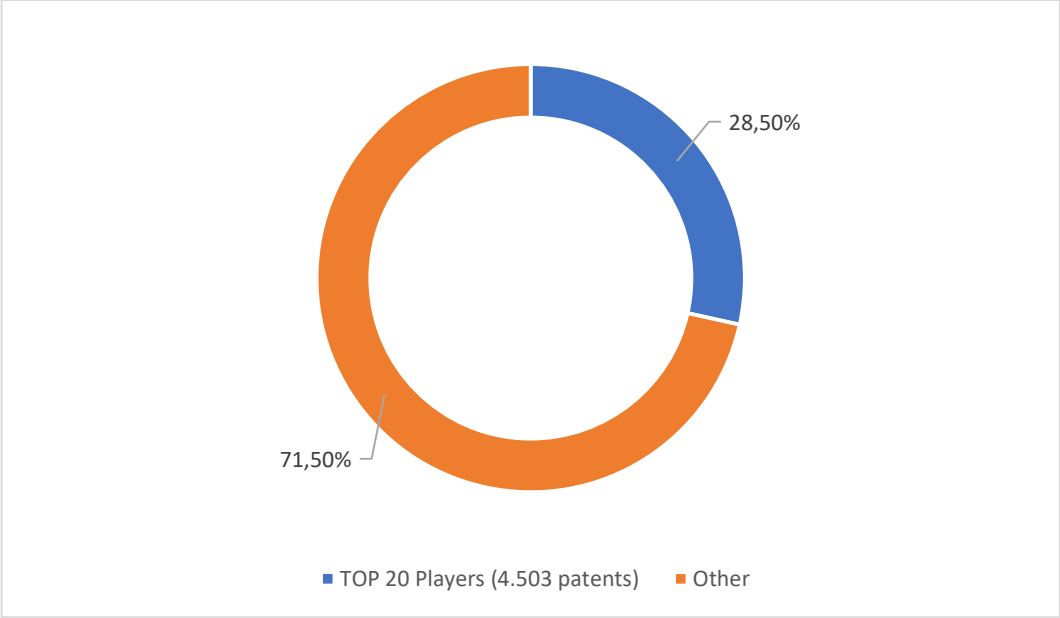

Figure 22: Share of the top twenty companies (28,5%) in relation to the total companies of the dataset obtained for Y02B.

For a more detailed look on the twenty firms that have brought more inventions to this sector, see the Figure 23 which follows. In first place with 628 published patents is SIGNIFY NV, a multinational lighting company formed in 2016 following the spin-off of Philips' lighting division. Coming in second spot with only about 20 patents less than the first, MITSUBISHI ELECTRIC CORP one of the world's largest companies in the production and sale of electrical and electronic products, and also one of the largest companies in the production of photovoltaic panels. LG ELECTRONICS INC. on the other hand, already encountered when discussing the major players for Waste Management ranks third with as many as 593 published patents.

In addition, as many as seven well-known companies involved in the production of electronic materials can be found in the ranking, such as: PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO LTD, SAMSUNG ELECTRONICS CO LTD, WHIRPOOL CORP., SIEMENS AKTIENGESELLSCHAFT, HUAWEI TECHNOLOGIES COMPANY LTD., BSH HAUSGERATE GMBH and KONINKLIJKE PHILIPS. For the field of lighting engineering and the production of components with LED and OLED technologies there is the firm ZUMTOBEL AG. There are also three companies dealing with air conditioning, air purification and heating system equipment, such as: DAIKIN INDUSTRIES LTD, ranked fifth; CARRIER

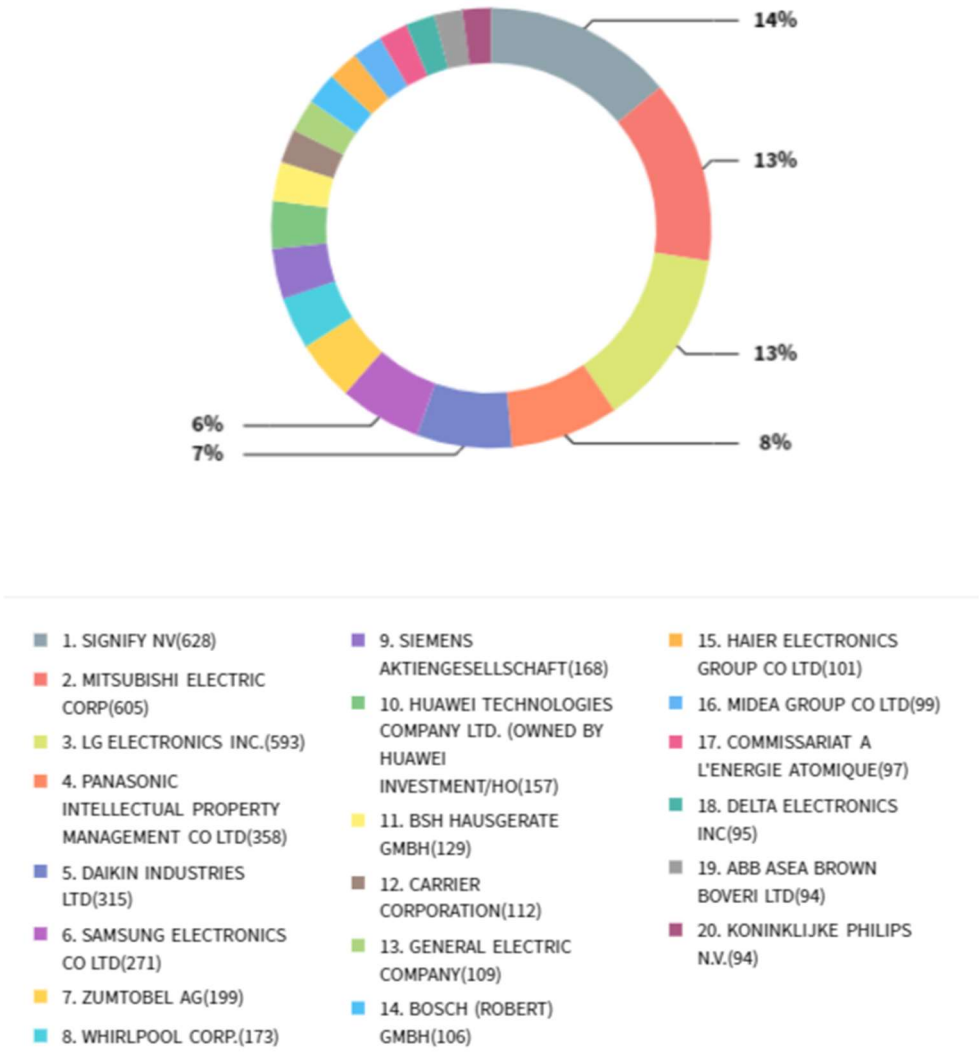

Figure 23: Percentage shares related to the number of patents per company based on the top 20 companies for Y02B.

Source: Derwent Innovation

CORPORATION in twelfth place; and HAIER ELECTRONICS GROUP CO LTD, in fifteenth position. Furthermore, there are three companies, namely MIDEA GROUP CO LTD, DELTA ELECTRONICS INC and ABB ASEA BROWN BOVERI LTD, whose main business is industrial automation. Additionally, on the automotive side we find two firms, already found among the 20 major players in Transportation, which are GENERAL ELECTRIC COMPANY and BOSCH GMBH. Finally, in seventeenth place is the COMMISSARIAT A L'ENERGIE ATOMIQUE, a research center, which also published innovative patents in the green field for the two IPC Green Inventory topics examined earlier.

Considering the sectors concerning the companies just mentioned, it can be seen that almost all of the companies, sixteen in all, are from the electronics sector and they are: MITSUBISHI ELECTRIC CORP, LG ELECTRONICS INC., PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO LTD, DAIKIN INDUSTRIES LTD, SAMSUNG ELECTRONICS CO LTD, WHIRPOOL CORP., SIEMENS AKTIENGESELLSCHAFT, HUAWEI TECHNOLOGIES COMPANY LTD, BSH HAUSGERATE GMBH, CARRIER CORPORATION, BOSCH GMBH, HAIER ELECTRONICS GROUP CO LTD, MIDEA GROUP CO LTD, DELTA ELECTRONICS INC, ABB ASEA BROWN BOVERI LTD and KONINKLIJKE PHILIPS N.V. The second largest sector includes two companies (SIGNIFY NV and ZUMTOBEL AG) and is related to lighting. There is also GENERAL ELECTRIC COMPANY which works in both the electronics and automotive sectors. Finally, to the nuclear and renewable energy sector there is the COMMISSARIAT A L'ENERGIE ATOMIQUE company.

4.4.4 Y02D

The main leaders in patent publication for Y02D will be analyzed in this subparagraph, as mentioned previously, this is the group concerning ICTs that aim to reduce their energy consumption. The best twenty innovative players in the field account for 64 percent (see Figure 24) of the dataset obtained through the query, which had identified a total of 12.097 patents.

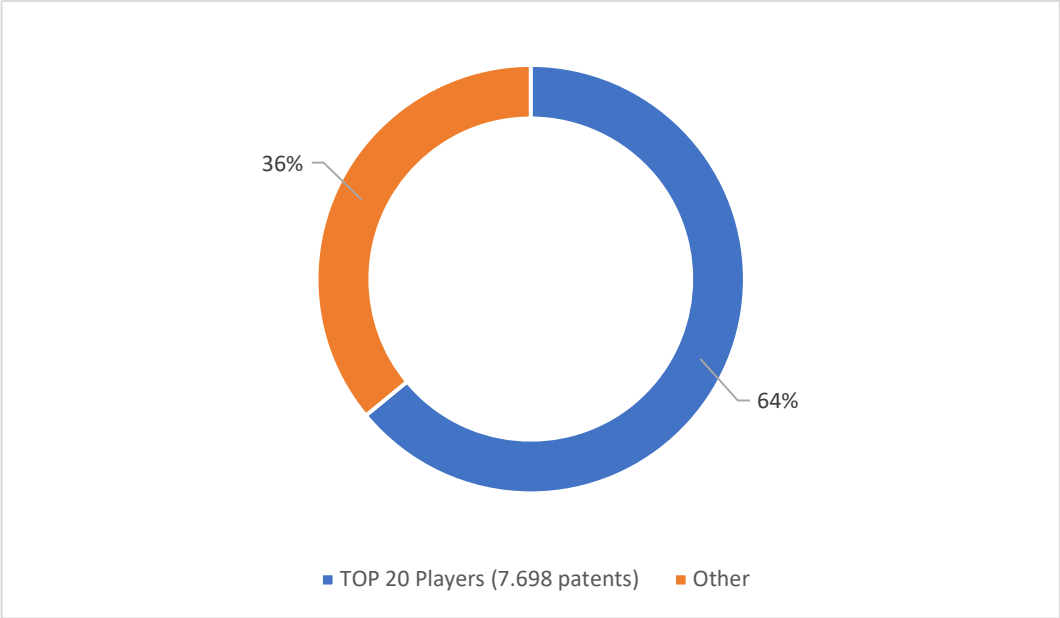

Figure 24: Share of the top twenty companies (64%) in relation to the total companies of the dataset obtained for Y02D.

In first place, as shown in the Figure 25, with more than a thousand published patents is HUAWEI TECHNOLOGIES COMPANY LTD. which had also proved to be an innovative company in the Y02B group. In second position, with a gap of 300 patents less QUALCOMM INC, a U.S. research and development company in the field of wireless telecommunications. While, ranked third is SAMSUNG ELECTRONICS CO LTD, which had also emerged as one of the top companies as far as Y02B is concerned.

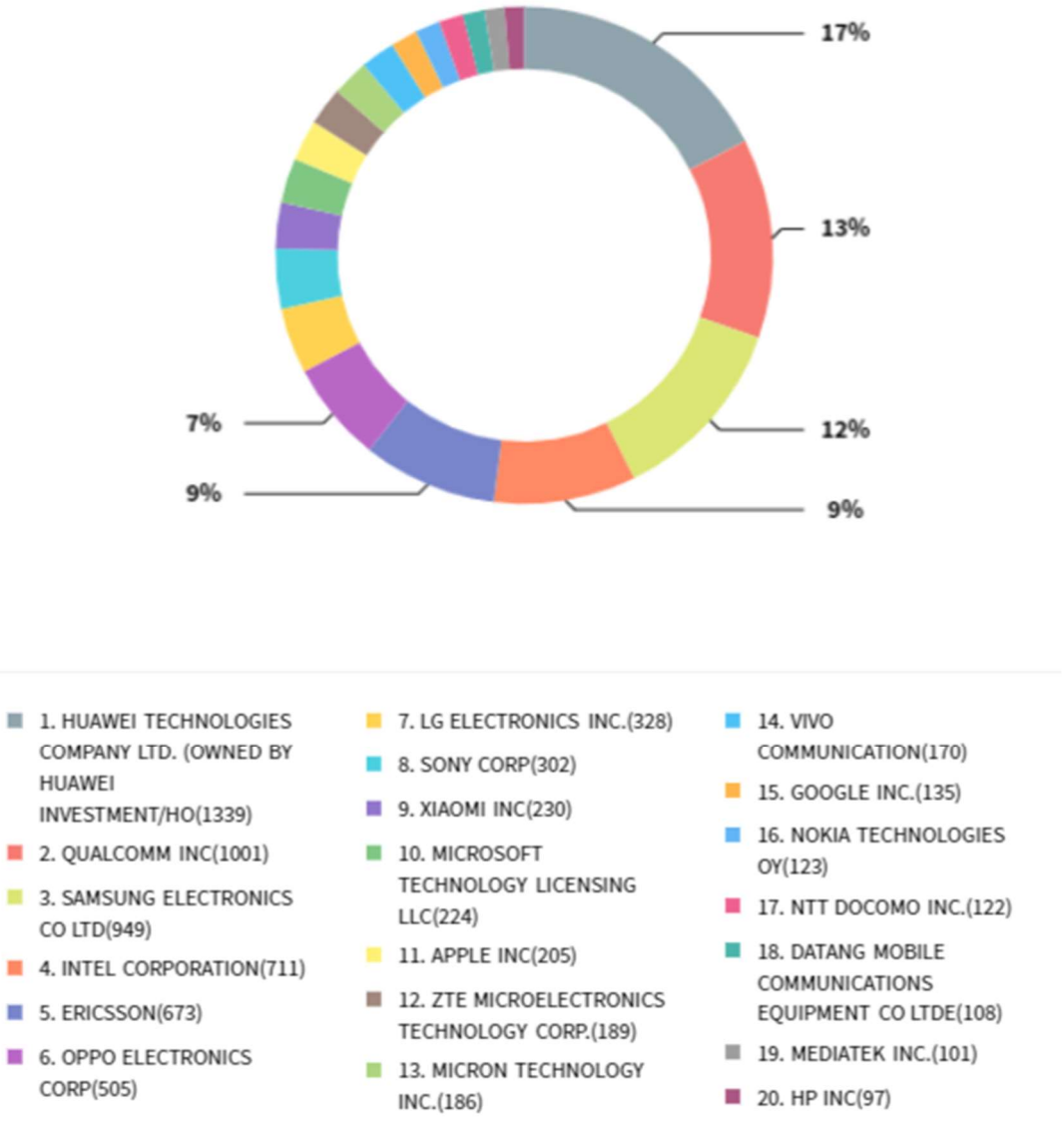

Figure 25: Percentage shares related to the number of patents per company based on the top 20 companies for Y02D.

Source: Derwent Innovation

Furthermore, as many as 5 telecommunication companies can be found in the classification, such as: ERICSSON (673 patents), ZTE MICROELECTRONICS CORP. (189 patents), NOKIA TECHNOLOGIES OY (123 patents), NTT DOCOMO INC. (122 patents), and finally DATANG MOBILE COMMUNICATIONS EQUIPMENT CO LTDE (108 patents). In fourth position and thirteenth position respectively are observed INTEL CORPORATION and MICRON TECHNOLOGY INC., both companies for the production of semiconductors, microprocessors, network components

and many other integrated circuits. There are also many consumer electronics manufacturing companies as many as 6, among which we find names that are also very famous: LG ELECTRONICS INC., OPPO ELECTRONICS CORP, SONY CORP, XIAOMI INC, APPLE INC, VIVO COMMUNICATION, MICROSOFT TECHNOLOGY LICENSING LLC (the latter is also a well-known multinational computer company). Lastly, in fifteenth place is GOOGLE INC, which as commonly known is a company that offers online services, in the penultimate position is discernible MEDIATEK INC. which sells components for smartphones, smart TVs, voice assistant devices and so on, and finally, in the last position is HP INC. which develops personal computers and related consumables.

Regarding the sectors of the companies listed previously, it can be seen that the two most important sectors are electronics (HUAWEI TECHNOLOGIES COMPANY LTD., SAMSUNG ELECTRONICS CO LTD, OPPO ELECTRONICS CORP, LG ELECTRONICS INC. and VIVO COMMUNICATION) and telecommunications (ERICSSON, ZTE MICROELECTRONICS TECHNOLOGY INC., NOKIA TECHNOLOGIES OY, NTT DOCOMO INC. and DATANG MOBILE COMMUNICATIONS EQUIPMENT CO LTDE). Then there is the semiconductor sector with three companies, INTEL CORPORATION, MICRON TECHNOLOGY INC. and MEDIATEK INC. In addition, there is QUALCOMM INC which is involved in both the semiconductor and telecommunications sectors. Finally, there is the information technology sector with two companies (GOOGLE INC. and HP INC) and there are as many as four companies dealing with both the sector just mentioned and the electronics sector (SONY CORP, XIAOMI INC, MICROSOFT TECHNOLOGY LICENSING LLC and APPLE INC).

4.5 Patent quality analysis

After conducting a quantitative analysis of the top 20 players in patent publication for each of the four chosen databases (Transportation, Waste Management, Y02B, and Y02D), it is useful at this point to look more deeply into which companies contribute the most to innovation with their patents.

In order to be able to measure the quality of a patent, the parameter to be taken into close consideration are the Forward Citations, which are the number of applications published subsequent to the publication in question

and that cite the invention, either by the patent owner or its examiner and according to the previous state of the art. These serve the function of an accurate indicator of how much a given patent contributes to the innovative and technological process of the sector under consideration. In fact, what is important is not the number of patents obtained, but rather how much the latter can be a starting point for develop further inventions later.

It is important to consider, however, that the mere number of citing patents is still not a good indicator of the value of a patent, since it depends on the date the patent was applied. In fact, as is easily guessed a younger publication will naturally have a lower probability of having been cited by a large number of patents, compared to an older one. For this very reason just expressed, a citation index is created to normalize the value by year, formulated as follows:

$$Patent\ Citation\ Index = \frac{Number\ of\ citing\ patents}{Age\ of\ the\ patent}$$

Where, the patent age is given by 2022 - Application year.

Thereafter, a further analysis was to sum the total Patent Citation Indexes for each company and average it over the patent production. In this way, a number was obtained that was also a function of the amounts of patents produced by each individual firm.

$$Average\ Citation\ Index = \frac{\sum_{i=1}^{n} Patent\ Citation\ Index_i}{\sum_{i=1}^{n} Patent_i}$$

Where, i corresponds to the i-th patent and n to the total number of patents of the Optimized Assignee considered.

Hence, these calculations are carried out for each of the 4 databases chosen and from the results only the top 20 innovators with the highest Average Citation Index are chosen.

To conclude, after finding the top 20 innovators, an additional analysis was performed using the Quadrant chart, in which the Average Citation Index of each assignee was correlated with innovation output, measured as the amount of patents registered. In the chart, quadrant boundaries were calculated by averaging over the index values and the number of total patents of the twenty innovators considered.

4.5.1 Transportation

Regarding the topic of Transportation, after completing the calculations on the indices mentioned in the previous paragraph 4.5, the following Table 5 is obtained, which shows the leading twenty companies reordered according to the total number of patents. The Share on the total of the entire dataset of 1.640 of each assignee and the Average Citation Index can also be observed in the table below.

Table 5: Top 20 companies in Transportation by portfolio size, with relative market share and portfolio.

N.	FIRM	TOT. PATENTS	SHARE OF TOTAL	AVERAGE CITATION INDEX
1	LG CHEM LTD.	48	2,93%	0,06
2	SIEMENS MOBILITY	48	2,93%	0,04
3	ALSTOM TRANSPORT SA	33	2,01%	0,07
4	TOSHIBA CORP	26	1,59%	0,05
5	SAMSUNG SDI CO LTD	24	1,46%	0,12
6	BOMBARDIER TRANSPORTATION BUSINESS	23	1,40%	0,10
7	VOLVO AB	21	1,28%	-
8	COMMISSARIAT A L'ENERGIE ATOMIQUE	18	1,10%	0,05
9	CRRC CORPORATION	18	1,10%	0,02
10	GENERAL ELECTRIC COMPANY	17	1,04%	0,06
11	HITACHI LTD	16	0,98%	0,19
12	BOSCH (ROBERT) GMBH	16	0,98%	0,03
13	VALEO S.A.	15	0,91%	0,11
14	MITSUBISHI ELECTRIC CORP	15	0,91%	0,08
15	HITACHI CONSTRUCTION MACHINERY CO LTD	15	0,91%	0,04
16	BYD CO LTD	15	0,91%	-
17	DAEWOO SHIPBUILDING & MARINE ENGINEERING CO LTD	14	0,85%	0,08
18	VOLKSWAGEN A.G.	14	0,85%	0,01
19	SNCF SOC NAT CHEMINS DE FER	13	0,79%	0,12
20	COMPAGNIE PLASTIC OMNIUM	13	0,79%	0,05
	TOTAL	422	25,73%	

Compared with the previous analysis carried out in the paragraph 4.4.1, there are no particular discrepancies in the classification obtained through Excel,

except that by the data cleaning carried out on the extracted database, one more patent is found for HITACHI CONSTRUCTION MACHINERY CO LTD.

The quadrant chart, in Figure 26, showed the placement of the top twenty companies in the previous table, based on their total patent output related to the calculated Average Citation Index. According to the results, LG CHEM

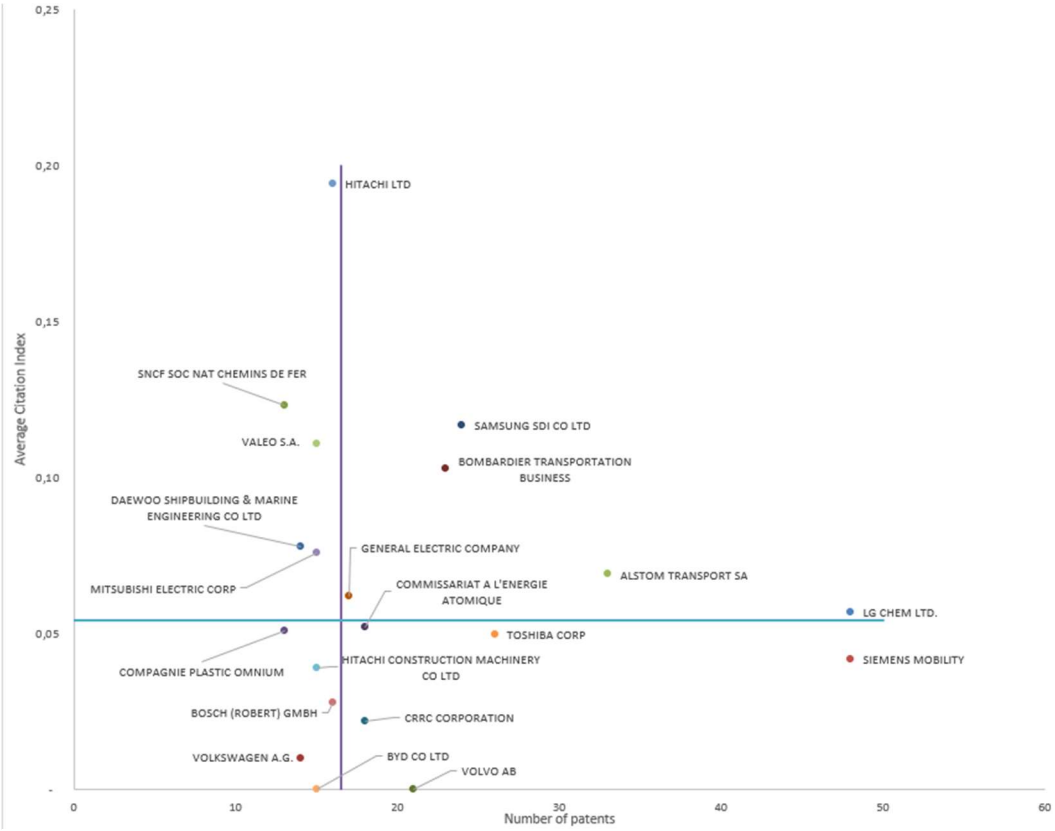

Figure 26: Quadrant chart in Transportation by Average Citation Index and number of patents.

LTD. and SIEMENS MOBILITY both have high patent numbers (48 patents), but in terms of the Average Citation Index the one of LG CHEM LTD. is slightly better. These two companies just mentioned can be identified as the leading firms in the industry. ALSTOM TRANSPORT SA which appears to be third in the ranking with 33 total patents has a marginally better Average Index than that of LG CHEM LTD., in fact in the graph this company is in the third quadrant. With the companies SAMSUNG SD CO LTD and BOMBARDIER TRANSPORTATION BUSINESS the number of patents still decreases, about twenty for both of them, but there is a significant improvement in the Average Citation Index. Meanwhile, HITACHI LTD,

tenth in the ranking, is the company with the highest Average Citation Index for the industry.

In a nutshell, the green transportation sector at the moment does not have a real prototype of a company, in fact it can be seen that among the companies that most contribute to the development of new green innovations for transportation there are different types of businesses, some dealing with train construction, others more focused on the production of electrical components and so on. It is important to emphasize above all that therefore that there are not only companies that make transportation as the core business of the activity, but also types of companies not primarily related to the production of transportation machineries.

4.5.2 Waste Management

The attention is shifted to the second group of the IPC Green Inventory that was analyzed, the Waste Management, whose dataset obtained through query consists of 4.850 patents. From the Table 6 shown in the following, it can be seen, similarly to before, the current ranking of the top twenty companies, that are the most innovation-driven, reordered according to the total number of patents made by each one, with the corresponding share over the total for every firm and the Average Citation Index.

Table 6: Top 20 companies in Waste Management by portfolio size, with relative market share and portfolio.

N.	FIRM	TOT. PATENTS	SHARE OF TOTAL	AVERAGE CITATION INDEX
1	SUEZ ENVIRONNEMENT CO SA	46	0,95%	0,03
2	SCANIA AB	46	0,95%	0,01
3	PSA AUTIMOBILES SA	45	0,93%	0,05
4	VEOLIA ENVIRONNEMENT	45	0,93%	0,04
5	VOLKSWAGEN A.G.	37	0,76%	0,19
6	CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIC	37	0,76%	-
7	BASF SE	34	0,70%	0,01
8	DOOSAN HOLDING	30	0,62%	0,15
9	SAUDI ARABIAN OIL COMPANY (SAUDI ARAMCO)	27	0,56%	-
10	MITSUBISHI HEAVY INDUSTRIES LTD.	26	0,54%	0,09

11	LG ELECTRONICS INC.	25	0,52%	0,06
12	KONINKLIJKE PHILIPS N.V.	24	0,49%	0,02
13	L'AIR LIQUIDE S.A.	24	0,49%	0,01
14	ECOLAB INC.	22	0,45%	-
15	COMMISSARIAT A L'ENERGIE ATOMIQUE	21	0,43%	-
16	YARA INTERNATIONAL ASA	20	0,41%	0,01
17	EVOQUA WATER TECHNOLOGIES LLC	20	0,41%	-
18	MAN SE	19	0,39%	0,05
19	LG CHEM LTD.	18	0,37%	0,03
20	SOLVAY S.A.	18	0,37%	0,03
	TOTAL	584	12,04%	

It is immediate to note that compared to the quantitative analysis carried out in the previous sub-section 4.4.2, there is no variation on the quantities of patents for companies obtained from cleaning the data on Excel.

A quadrant chart, which relates the total number of patents for each company to the Average Citation Index, is shown in the Figure 27 that follows, with

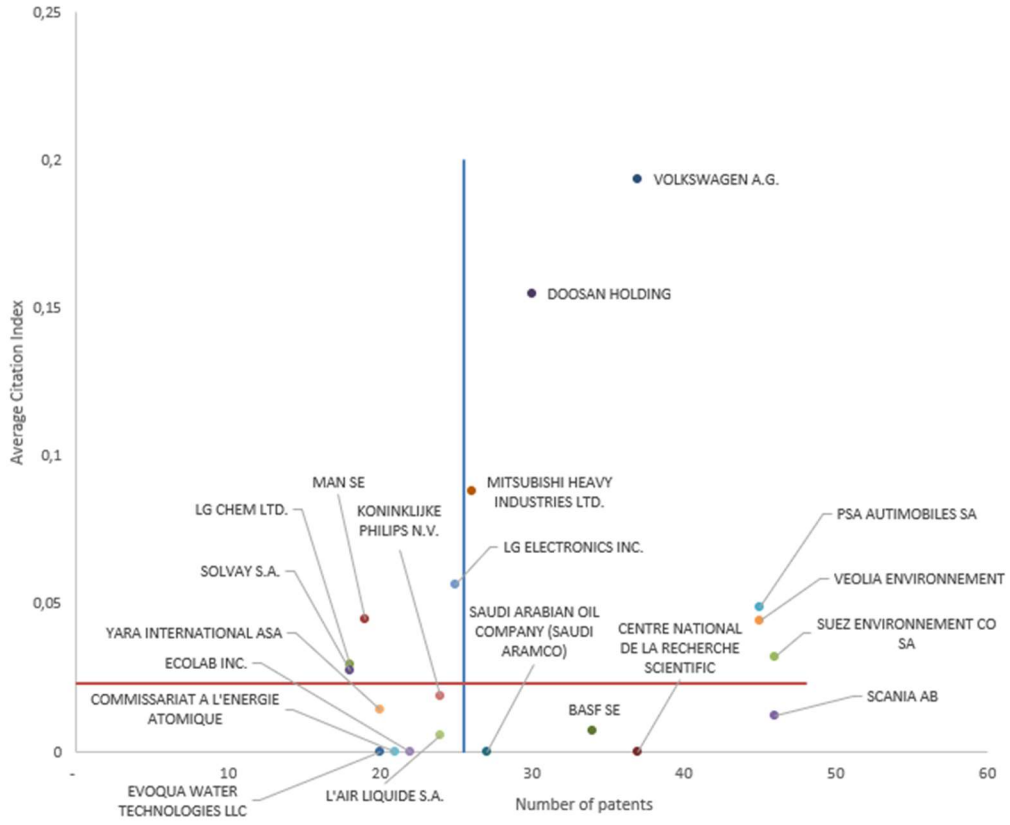

Figure 27: Quadrant chart in Waste Management by Average Citation Index and number of patents.

the ultimate purpose of allowing the immediate identification of the

companies of greatest interest to the field in consideration. The analysis of the chart reveals clearly that there are four companies that contribute the most to the growth of innovation in this green sector. In order of descending Average Citation Index these are: PSA AUTIMOBILES SA, VEOLIA ENVIRONNEMENT, SUEZ ENVIRONNEMENT CO SA, and, finally, SCANIA AB. The first two listed have both 45 patents, while the latter are detached from the others by both having one more patent. VOLKSWAGEN A.G. and DOOSAN HOLDING, with an amount of 37 and 30 patent documents filed, respectively, break away from this group by about a dozen fewer patents, but with a significantly higher Average Citation Index (0.19 and 0.15). In comparison, the two companies CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIC and BASF SE, that ranked sixth and seventh, both have portfolios with about thirty patents for the Waste Management field, but a very low Average Citation Index, for the first mentioned corresponding even to zero.

In summary, this analysis shows that at the moment in the Waste Management sector the companies that contribute mostly to the development of new environmentally supportive innovations are companies that already deal with water and waste management in their business plan (such as VEOLIA and SUEZ), but not only these whose business coincides perfectly with the related group of the IPC Green Inventory considered, also companies that deal with the production of industrial vehicles or cars make a great contribution to the development of new green technologies in this field.

4.5.3 Y02B

In this sub-section the first selected group of the Y02 classification is analyzed, that is, Y02B, which is made up of a total of 15.816 patents. To get a more detailed look at the twenty companies that lead the most innovativeness in this area, the following Table 7 is provided, where for each corporation is given the Average Citation Index, its share of the total, and the sorting is done in descending order of the total number of patents.

Table 7: Top 20 companies in Y02B by portfolio size, with relative market share and portfolio.

N.	FIRM	TOT. PATENTS	SHARE OF TOTAL	AVERAGE CITATION INDEX
1	SIGNIFY NV	629	3,98%	0,01
2	MITSUBISHI ELECTRIC CORP	606	3,83%	0,04

3	LG ELECTRONICS INC.	593	3,75%	0,10
4	PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO LTD	358	2,26%	0,04
5	DAIKIN INDUSTRIES LTD	315	1,99%	0,05
6	SAMSUNG ELECTRONICS CO LTD	271	1,71%	0,07
7	ZUMTOBEL AG	199	1,26%	0,03
8	WHIRLPOOL CORP.	173	1,09%	0,03
9	SIEMENS AKTIENGESELLSCHAFT	168	1,06%	0,07
10	HUAWEI TECHNOLOGIES COMPANY LTD. (OWNED BY HUAWEI INVESTMENT/HOLDING	157	0,99%	0,02
11	BSH HAUSGERATE GMBH	129	0,82%	0,10
12	CARRIER CORPORATION	112	0,71%	0,02
13	GENERAL ELECTRIC COMPANY	109	0,69%	0,06
14	BOSCH (ROBERT) GMBH	106	0,67%	0,07
15	HAIER ELECTRONICS GROUP CO LTD	101	0,64%	0,01
16	MIDEA GROUP CO LTD	99	0,63%	0,01
17	COMMISSARIAT A L'ENERGIE ATOMIQUE	97	0,61%	0,06
18	DELTA ELECTRONICS INC	95	0,60%	0,08
19	ABB ASEA BROWN BOVERI LTD	94	0,59%	0,10
20	KONINKLIJKE PHILIPS N.V.	94	0,59%	0,02
	TOTAL	4505	28,48%	

Compared to the analysis carried out in the subsection 4.4.3 through the database cleanup performed on Excel one more patent is found for both SIGNIFY NV and MITSUBISHI ELECTRIC CORP, the remaining patent amounts for the other companies remain unchanged.

A quadrant chart is then provided (Figure 28) that relates the third and fifth columns of Table 7, i.e., the company's total patent portfolio to the Average Citation Index. Based on this analysis, it is clear that three firms are the major drivers in supporting the development of this group for climate change adaptation. The first company to contribute with an as many as 629 patents is SIGNIFY NV, in second place comes MITSUBISHI ELECTRIC CORP, which breaks away from the previous one by about twenty fewer patents and by having a higher Average Citation Index. Immediately after in third position ranks LG ELECTRONICS INC. which has a total of 593 patents, but in comparison with the previous two companies it has a significantly

higher Average Citation Index, among the best in this category. Finally, with a considerable minority of patents compared to these top three industry

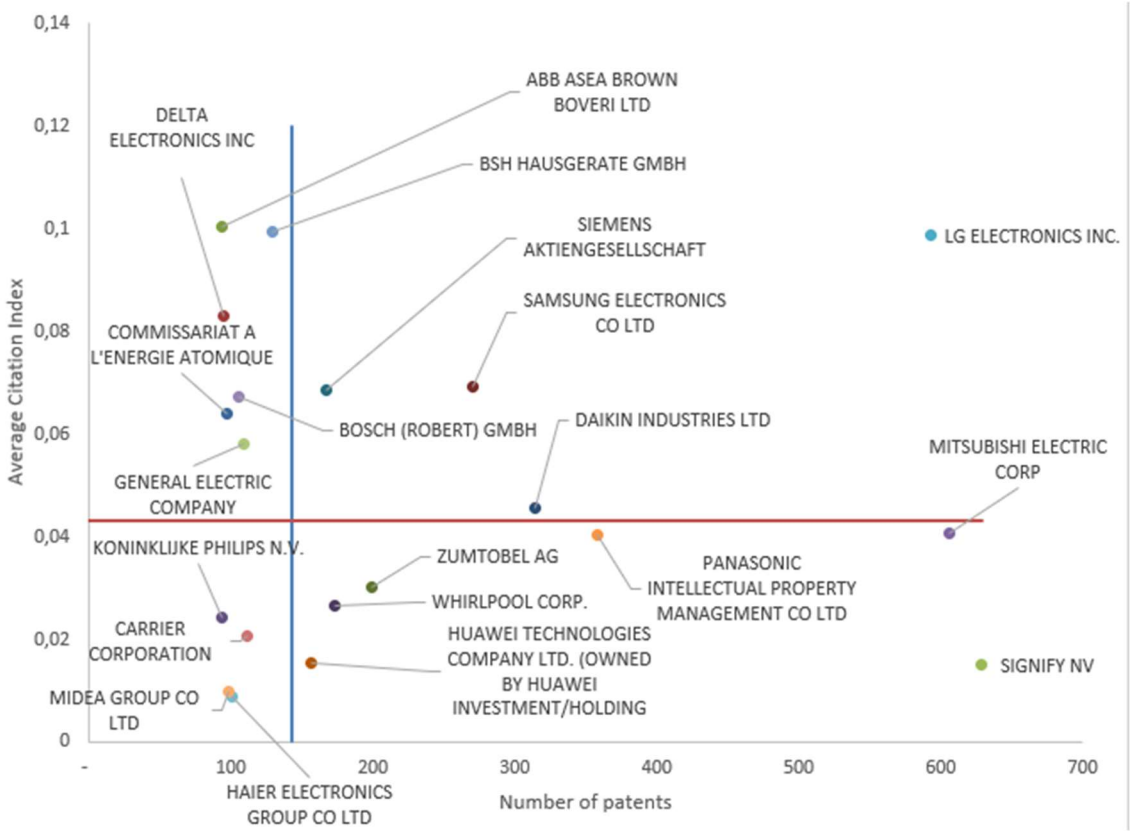

Figure 28: Quadrant chart in Y02B by Average Citation Index and number of patents.

leaders stand PANASONIC INTELLECTUAL PROPERTY MANAGEMENT CO LTD and DAIKIN INDUSTRIES LTD, both with an Average Citation Index in the mid-range for the group considered. SAMSUNG ELECTRONICS CO LTD and SIEMENS AKTIENGESELLSCHAFT, 271 and 168 patents respectively, also contribute to the development and growth of innovations as both of them have a fairly high Average Citation Index.

In conclusion, for the Y02B group related to buildings (including housing and appliances or end-user applications), it is immediately clear that the companies that most support and contribute to the origination and development of new technologies in this sector are large multinational companies operating mainly in the electrical and electronics sector, as

reflected as well by the top three leaders in this sector: SIGNIFY NV, MITSUBISHI ELECTRIC CORP and LG ELECTRONICS INC.

4.5.4 Y02D

The last group analyzed is Y02D, which comprises a total of 12.097 patents. The Table 8 is also provided for the latter, where similarly to the previous analyses one can find the current best twenty companies re-ordered according to the overall number of patents published by each, along with the relative share of the total for every company and the Average Citation Index.

Table 8: Top 20 companies in Y02D by portfolio size, with relative market share and portfolio.

N.	FIRM	TOT. PATENTS	SHARE OF TOTAL	AVERAGE CITATION INDEX
1	HUAWEI TECHNOLOGIES COMPANY LTD. (OWNED BY HUAWEI INVESTMENT/HOLDING	1343	11,10%	0,02
2	QUALCOMM INC	1005	8,31%	0,01
3	SAMSUNG ELECTRONICS CO LTD	952	7,87%	0,05
4	INTEL CORPORATION	712	5,89%	0,04
5	ERICSSON	674	5,57%	0,02
6	OPPO ELECTRONICS CORP	508	4,20%	0,02
7	LG ELECTRONICS INC.	329	2,72%	0,09
8	SONY CORP	302	2,50%	0,03
9	XIAOMI INC	231	1,91%	0,05
10	MICROSOFT TECHNOLOGY LICENSING LLC	224	1,85%	0,00
11	APPLE INC	205	1,69%	0,04
12	ZTE MICROELECTRONICS TECHNOLOGY CORP.	193	1,60%	0,04
13	MICRON TECHNOLOGY INC.	188	1,55%	-
14	VIVO COMMUNICATION	170	1,41%	0,02
15	GOOGLE INC.	141	1,17%	0,02
16	NOKIA TECHNOLOGIES OY	124	1,03%	0,04
17	NTT DOCOMO INC.	122	1,01%	0,05
18	DATANG MOBILE COMMUNICATIONS EQUIPMENT CO LTDE	108	0,89%	0,02
19	MEDIATEK INC.	101	0,83%	0,06
20	HP INC	97	0,80%	0,02
	TOTAL	7729	63,89%	

In this case, compared to the quantitative analysis carried out in the previous sub-section 4.4.4 which was done using the automatic analysis of the Derwent database, by exporting the data to Excel and its cleanup some increase in the number of patents is found for the following companies: HUAWEI TECHNOLOGIES COMPANY LTD, QUALCOMM INC, SAMSUNG ELECTRONICS CO LTD, INTEL CORPORATION, ERICSSON, OPPO ELECTRONICS CORP, LG ELECTRONICS INC., XIAOMI INC, ZTE MICROELECTRONICS TECHNOLOGY CORP., MICRON TECHNOLOGY INC., GOOGLE INC. and, finally, NOKIA TECHNOLOGIES OY. Despite, these changes however, the ranking positions still remain the same.

A quadrant chart is provided, Figure 29 that follows, in order to obtain an at-a-glance view immediately of the companies that contribute the most to innovation for this sector. The first company in terms of number of patents filed turns out to be HUAWEI TECHNOLOGIES COMPANY LTD.,

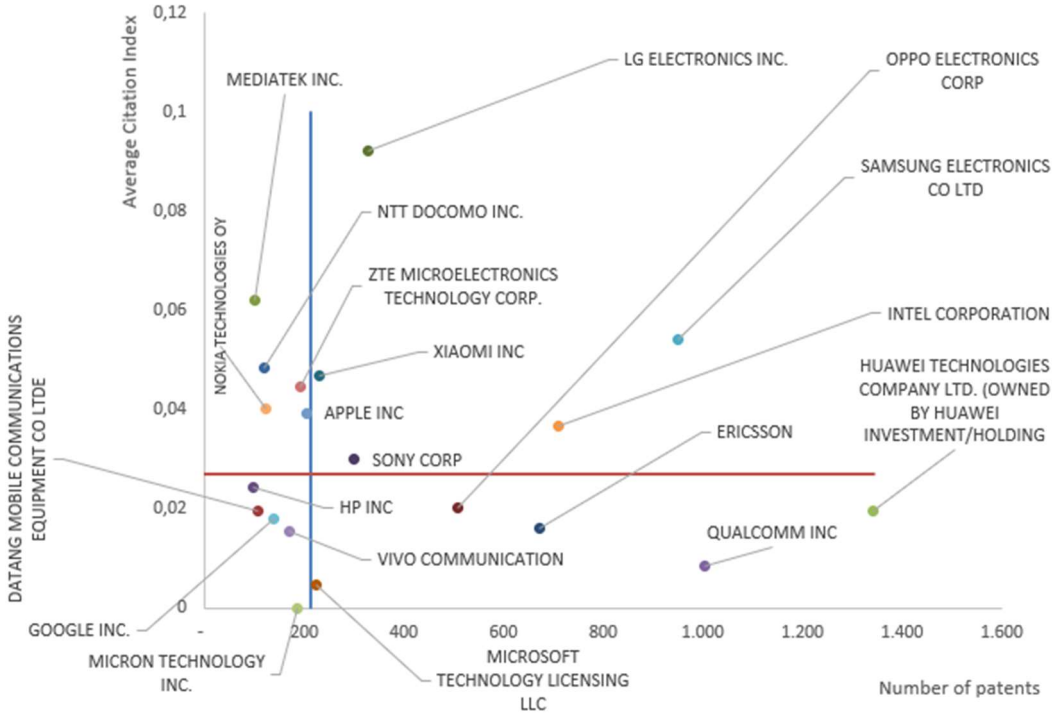

Figure 29: Quadrant chart in Y02D by Average Citation Index and number of patents.

followed right after with an impressive detachment of 300 patents less by QUALCOMM INC, both companies, however, have an Average Citation Index below the industry average. In contrast, both SAMSUNG ELECTRONICS CO LTD and INTEL CORPORATION, third and fourth respectively in terms of the number of patents granted, have a higher Average

Citation Index than the top two in the ranking, in fact are located in the third quadrant of the graph. Also very significant is the contribution made by the company LG ELECTRONICS INC. which has 329 patents in total and the highest Average Citation Index of the entire sector under examination.

In summary, for this sector related to ICTs that aim to reduce their energy consumption, the companies that bring the greatest breakthroughs to innovation are those related to the production of electrical and electronic equipment and the telecommunications industry.

CONCLUSION

The technological evolution for the green sector is constantly progressing and seems destined to be a positive trend over time thanks to the countless studies conducted by both different companies and research centers. The focus on green innovations is high because, as mentioned previously, the latter allow maximizing efficiency by reducing waste and resource use, and for this specific reason they represent an opportunity for companies.

This thesis work sought to highlight different aspects related to green sector trends over the past eight years with regard to the European market. This was achieved by focusing on the two classifications: IPC Green Inventory (WIPO) and Y02 (EPO). Initially giving an insight into the patent quantities published for each topic of the two different classifications.

This initial analysis showed that for the green classification drawn up by WIPO, the ranking of the top three topics most prone to innovation turns out to be: Alternative Energy Production, Waste Management and Energy Conservation. While, for the classification related to climate change adaptation made by EPO as ranking the top three for bringing the most innovation are: Y02E (concerning climate change mitigation technologies in power generation, transmission and distribution), Y02T (concerning transportation-related climate change mitigation technologies) and Y02P (regarding climate change mitigation technologies in the production or manufacturing of goods).

After this analysis the focus has been on two topics in the IPC Green Inventory (Transportation and Waste Management) and two groups in Y02 (Y02B and Y02D). As observed, for all four chosen databases the trend of publications appears to have been steadily growing for several years, an indication that the technological advent has not yet saturated over time. The market also appears to be constantly evolving and more and more companies are trying to approach the green sector by offering innovative technologies.

Through the definition of the Average Citation Index, the main innovators for each dataset were analyzed by evaluating them for patent portfolio size and quality of patent ideas.

The major players with regard to the topic of Transportation turn out to be LG CHEM LTD. and SIEMENS MOBILITY, the former being a company whose industry is electronics and the latter focused on railway engineering.

Most of the companies contributing to the creation of innovative technologies in this area belong to these two sectors just mentioned.

Regarding the Waste Management group, the companies that stood out for contributing the most to innovation are: SUEZ ENVIRONNEMENT CO SA, SCANIA AB, PSA AUTOMOBILES SA, VEOLIA ENVIRONNEMENT. SUEZ and VEOLIA are companies concerning the waste disposal treatment services sector, while, SCANIA concerns engineering and PSA the automotive sector.

The leading companies in the Y02B sector (relating to building, including housing and appliances or related end-user applications) are: SIGNIFY NV, MITSUBISHI ELECTRIC CORP, and LG ELECTRONICS INC. In this case, the companies' sectors cover the lighting sector for SIGNIFY and the electronics sector for the second and third in the ranking. The latter sector turns out to be the most used by the companies in the top 20, in fact as many as sixteen companies are part of it.

Finally, with regard to the Y02D group (concerning ICTs that aim to reduce their energy consumption) the companies that bring the most innovations are: HUAWEI TECHNOLOGIES COMPANY LTD., QUALCOMM INC and SAMSUNG ELECTRONICS CO LTD. The first two mentioned have a below-average Average Citation Index, while the third in the ranking has a higher Average Citation Index. Of these three companies on the podium HUAWEI and SAMSUNG belong to the electronics sector, while QUALCOMM belongs to the telecommunications sector, both of which are among the most populous sectors of companies.

Future prospects point to the continuing and growing trend of all the major groups in the IPC Green Inventory and Y02, and it is very likely that over time new companies that do not currently hold central roles will join this market. In fact, the number of companies that are conducting research, and thus investing in green, appears to be growing rapidly, so competition in this area is likely to increase in the future. At this stage, however, the attractiveness, economic opportunities and incentives proposed by states that a pro-environmental choice can offer in the near future are high and will cause the market to grow further. In addition, the collaborative and synergistic activity among heterogeneous sectors for each green topic could be the key to achieving new solutions to counter and combat climate change.

In conclusion, it is possible to assume that interest in the green field is set to grow and will become one of the most important sectors in the future in

economic terms since these innovations will be increasingly used to combat climate change with the aim of improving people's health and lives.

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https://www.epo.org/news-events/in-focus/classification/classification/updatesYO2andY04S.html

APPENDIX 1: IPC Green Inventory (WIPO) classification scheme

Source: https://www.wipo.int/classifications/ipc/green-inventory/home

TOPIC	SUB-TOPICS AND IPC
ALTERNATIVE ENERGY PRODUCTION	❖ **BIO-FUELS** ➢ SOLID FUELS (C10L 5/00, 5/40-5/48) ▪ TORREFACTION OF BIOMASS (C10B 53/02, C10L 5/40, 9/00) ➢ LIQUID FUELS (C10L 1/00, 1/02, 1/14) ▪ VEGETABLE OILS (C10L 1/02, 1/19) ▪ BIODIESEL (C07C 67/00, 69/00, C10G, C10L 1/02, 1/19, C11C 3/10, C12P 7/649) ▪ BIOETHANOL (C10L 1/02, 1/182, C12N 9/24, C12P 7/06-7/14) ➢ BIOGAS (C02F 3/28, 11/04, C10L 3/00, C12M 1/107, C12P 5/02) ❖ **FROM GENETICALLY ENGINEERED ORGANISMS** (C12N 1/13, 1/15, 1/21, 5/10, 15/00, A01H) ❖ **INTEGRATED GASIFICATION COMBINED CYCLE (IGCC)** (C10L 3/00, F02C 3/28) ❖ **FUEL CELLS** (H01M 4/86-4/98, 8/00-8/24, 12/00-12/08) ➢ ELECTRODES (H01M 4/86-4/98) ➢ INERT ELECTRODES WITH CATALYTIC ACTIVITY (H01M 4/86-4/98) ➢ NON-ACTIVE PARTS (H01M 8/00-8/24, 50/00-50/171) ➢ WITHIN HYBRID CELLS (H01M 12/00-12/08) ❖ **PYROLYSIS OR GASIFICATION OF BIOMASS** (C10B 53/00 C10J) ❖ **HARNESSING ENERGY FROM MANMADE WASTE** ➢ AGRICULTURAL WASTE (C10L 5/00) ▪ FUEL FROM ANIMAL WASTE AND CROP RESIDUES (C10L 5/42, 5/44) ▪ INCINERATORS FOR FIELD, GARDEN OR WOOD WASTE (F23G 7/00-7/10) ➢ GASIFICATION (C10J 3/02, 3/46, F23B 90/00 F23G 5/027) ➢ CHEMICAL WASTE (B09B 3/00, F23G 7/00) ➢ INDUSTRIAL WASTE (C10L 5/48, F23G 5/00, 7/00) ▪ USING TOP GAS IN BLAST FURNACES TO POWER PIG-IRON PRODUCTION (C21B 5/06) ▪ PULP LIQUORS (D21C 11/00) ▪ ANAEROBIC DIGESTION OF INDUSTRIAL WASTE (A62D 3/02, C02F 11/04, 11/14) ▪ INDUSTRIAL WOOD WASTE (F23G 7/00, 7/10) ➢ HOSPITALWASTE (B09B 3/00, F23G 5/00) ➢ LANDFILL GAS (B09B) ▪ SEPARATION OF COMPONENTS (B01D 53/02, 53/04, 53/047, 53/14, 53/22, 53/24) ➢ MUNICAPAL WASTE (C10L 5/46, F23G 5/00) ❖ **HYDRO ENERGY** ➢ WATER-POWER PLANTS (E02B 9/00-9/06) ▪ TIDE OR WAVE POWER PLANTS (E02B 9/08) ➢ MACHINES OR ENGINES FOR LIQUIDS (F03B, F03C) ▪ USING WAVE OR TIDE ENERGY (F03B 13/12-13/26) ➢ REGULATING, CONTROLLING OR SAFETY MEANS OF MACHINES OR ENGINES (F03B 15/00-15/22) ➢ PROPULSION OF MARINEVESSELS USING ENERGY DERIVED FROM WATER MOVEMENT (B63H 19/02, 19/04) ❖ **OCEAN THERMAL ENERGY CONVERSION (OTEC)** (F03G 7/05) ❖ **WIND ENERGY**

(F03D)
- STRUCTURAL ASSOCIATION OF ELECTRIC GENERATOR WITH MECHANICAL DRIVING MOTOR (H02K 7/18)
- STRUCTURAL ASPECTS OF WIND TURBINES (B63B 35/00, E04H 12/00, E03D 13/00)
- PROPULSION OF VEHICLESUSING WIND POWER (B60K 16/00)
  - ELECTRIC PROPULSION OF VEHICLES USING WIND POWER (B60L 8/00)
- PROPULSION OF MARINE VESSELS BY WIND-POWERED MOTORS (B63H 13/00)

❖ **SOLAR ENERGY**
(F24S, H02S)
- PHOTOVOLTAICS (PV)
  - DEVICES ADAPTED FOR THE CONVERSION OF RADIATION ENERGY INTO ELECTRICAL ENERGY (H01L 27/142, 31/00-31/078, H01G 9/20, H02S 10/00)
    - USING ORGANIC MATERIALS AS THE ACTIVE PART (H01L 27/30, 51/42-51/48)
  - ASSEMBLIES OF A PLURALITY OF SOLAR CELLS (H01L 25/00, 25/03, 25/16, 25/18, 31/042)
  - SILICON; SINGLE-CRYSTAL GROWTH (C01B 33/02, C23C 14/14, 16/24, C30B 29/06)
  - REGULATING TO THE MAXIMUM POWER AVAILABLE FROM SOLAR CELLS (G05F 1/67)
  - ELECTRIC LIGHTING DEVICES WITH, OR RECHARGEABLE WITH, SOLAR CELLS (F21L 4/00, F21S 9/03)
  - CHARGING BATTERIES (H02J 7/35)
  - DYE-SENSITISED SOLAR CELLS (DSSC) (H01G 9/20, H01M 14/00)
- USE OF SOLAR HEAT (F24S)
  - FOR DOMESTIC HOT WATER SYSTEMS (F24D 17/00, 18/00)
  - FOR SPACE HEATING (F24D 3/00, 5/00, 11/00, 19/00)
  - FOR SWIMMING POOLS (F24S 90/00)
  - SOLAR UPDRAFT TOWERS (F03D 1/04, 9/00, 13/20, F03G 6/00)
  - FOR TREATMENT OF WATER, WASTE WATER OR SLUDGE (C02E 1/14)
  - GAS TURBINE POWER PLANTS USING SOLAR HEAT SOURCE (F02C 1/05)
- HYBRID SOLAR THERMAL-PV SYSTEMS (H01L 31/0525, H02S 40/44)
- PROPULSION OF VEHICLES USING SOLAR POWER (B60K 16/00)
  - ELECTRIC PROPULSION OF VEHICLES USING SOLAR POWER (B60L 8/00)
- PRODUCING MECHANICAL POWER FROM SOLAR ENERGY (F03G 6/00-6/06)
- ROOF COVERING ASPECTS OF ENERGY COLLECTING DEVICES (E04D 13/00, 13/18)
- STEAM GENERATION USING SOLAR HEAT (F22B 1/00, F24V 30/00)
- REFRIGERATION OR HEAT PUMP SYSTEMS USING SOLAR ENERGY (F25B 27/00)
- USE OF SOLAR ENERGY FOR DRYING MATERIALS OR OBJECTS (F26B 3/00, 3/28)
- SOLAR CONCENTRATORS (F24S 23/00, G02B 7/183)
- SOLAR PONDS (F24S 10/10)

❖ **GEOTHERMAL ENERGY**
(F24T)
- USE OF GEOTHERMAL HEAT (F01K, F24F 5/00, F24T 10/00-50/00, H02N 10/00, F25B 30/06)
- PRODUCTION OF MECHANICAL POWER FROM GEOTHERMAL ENERGY (F03G 4/00-4/06, 7/04)

❖ **OTHER PRODUCTION OR USE OF HEAT, NOT DERIVED FROM COMBUSTION, E.G. NATURAL HEAT**
(F24T 10/00-50/00, F24V 30/00-50/00)

	➢ HEAT PUMPS IN CENTRAL HEATING SYSTEMS USING HEAT ACCUMULATED IN STORAGE MASSES (F24D 11/02) ➢ HEAT PUMPS IN OTHER DOMESTIC- OR SPACE-HEATING SYSTEMS (F24D 15/04) ➢ HEAT PUMPS IN DOMESTIC HOT-WATER SUPPLY SYSTEMS (F24D 17/02, 18/00) ➢ AIR OR WATER HEATERS USING HEAT PUMPS (F24H 4/00) ➢ HEAT PUMPS (F25B 30/00) ❖ **USING WASTE HEAT** ➢ TO PRODUCE MECHANICAL ENERGY (F01K 27/00) ➢ OF COMBUSTION ENGINES (F01K 23/06-23/10, F01N 5/00, F02G 5/00-5/04, F25B 27/02) ➢ OF STEAM ENGINE PLANTS (F01K 17/00, 23/04) ➢ OF GAS-TURBINE PLANTS (F02C 6/18) ➢ AS SOURCE OF ENERGY FOR REFRIGERATION PLANTS (F25B 27/02) ➢ FOR TREATMENT OF WATER, WASTE WATER OR SEWAGE (C02F 1/16) ➢ RECOVERY OF WASTE HEAT IN PAPER PRODUCTION (D21F 5/20) ➢ FOR STEAM GENERATION BY EXPLOITATION OF THE HEAT CONTENT OF HOT HEAT CARRIERS (F22B 1/02) ➢ RECUPERATION OF HEAT ENERGY FROM WASTE INCINERATION (F23G 5/46) ➢ ENERGY RECOVERY IN AIR CONDITIONING (F24F 12/00) ➢ ARRANGEMENTS FOR USING WASTE HEAT FROM FURNACES, KILNS, OVENS OR RETORTS (F27D 17/00) ➢ REGENERATIVE HEAT-EXCHANGE APPARATUS (F28D 17/00-20/00) ➢ OF GASIFICATION PLANTS (C10J 3/86) ❖ **DEVICES FOR PRODUCING MECHANICAL POWER FROM MUSCLE ENERGY** (F03G 5/00-5/08)
TRANSPORTATION	❖ **VEHICLES IN GENERAL** ➢ HYBRID VEHICLES, E.G. HYBRID ELECTRIC VEHICLES (HEVS) (B60K 6/00, 6/20) ▪ CONTROL SYSTEMS (B60W 20/00) ▪ GEARINGS THEREFOR (F16H 3/00-3/78, 48/00-48/30) ➢ BRUSHLESS MOTORS (H02K 29/08) ➢ ELECTROMAGNETIC CLUTCHES (H02K 49/10) ➢ REGENERATIVE BRAKING SYSTEMS (B60L 7/10-7/22) ➢ ELECTRIC PROPULSION WITH POWER SUPPLY FROM FORCE OF NATURE, E.G. SUN, WIND (B60L 8/00) ➢ ELECTRIC PROPULSION WITH POWER SUPPLY EXTERNAL TO VEHICLE (B60L 9/00) ▪ WITH POWER SUPPLY FROM FUEL CELLS, E.G. FOR HYDROGEN VEHICLES (B60L 50/50-58/40) ➢ COMBUSTION ENGINES OPERATING ON GASEOUS FUELS, E.G. HYDROGEN (F02B 43/00, F02M 21/02, 27/02) ➢ POWER SUPPLY FROM FORCE OF NATURE, E.G. SUN, WIND (B60K 16/00) ➢ CHARGING STATIONS FOR ELECTRIC VEHICLES (H02J 7/00) ❖ **VEHICLES OTHER THAN RAIL VEHICLES** ➢ DRAG REDUCTION (B62D 35/00, 35/02, B63B 1/34-1/40) ➢ HUMAN-POWERED VEHICLE (B62K, B62M 1/00, 3/00, 5/00, 6/00) ❖ **RAIL VEHICLES** (B61) ➢ DRAG REDUCTION (B61D 17/02) ❖ **MARINE VESSEL PROPULSION** ➢ PROPULSIVE DEVICES DIRECTLY ACTED ON BY WIND (B63H 9/00)

	➢ PROPULSION BY WIND-POWERED MOTORS (B63H 13/00) ➢ PROPULSION USING ENERGY DERIVED FROM WATER MOVEMENT (B63H 19/02, 19/04) PROPULSION BY MUSCLE POWER (B63H 16/00) PROPULSION DERIVED FROM NUCLEAR ENERGY (B63H 21/18) ❖ **COSMONAUTIC VEHICLES USING SOLAR ENERGY** (B64G 1/44)
ENERGY CONSERVATION	❖ **STORAGE OF ELECTRICAL ENERGY** (B60K 6/28, B60W 10/26, H01M 10/44-10/46, H01G 11/00, H02J 3/28, 7/00, 15/00) ❖ **POWER SUPPLY CIRCUITRY** (H02J) ➢ WITH POWER SAVING MODES (H02J 9/00) ❖ **MEASUREMENT OF ELECTRICITY CONSUMPTION** (B60L 3/00, G01R) ❖ **STORAGE OF THERMAL ENERGY** (C09K 5/00, F244 7/00, F28D 20/00, 20/02) ❖ **LOW ENERGY LIGHTING** ➢ ELECTROLUMINESCENT LIGHT SOURCES (E.G. LEDS, OLEDS, PLEDS) (F21K 99/00, F21L 4/02, H01L 33/00-33/64, 51/50, H05B 33/00) ❖ **THERMAL BUILDING INSULATION** (E04B 1/62, 1/74-1/80, 1/88, 1/90) ➢ INSULATING BUILDING ELEMENTS (E04C 1/40, 1/41, 2/284-2/296) ▪ FOR DOOR OR WINDOW OPENINGS (E06B 3/263) ▪ FOR WALLS (E04B 2/00, E04F 13/08) ▪ FOR FLOORS (E04B 5/00, E04F 15/18) ▪ FOR ROOFS (E04B 7/00, E04D 1/28, 3/35, 13/16) ▪ FOR CEILINGS (E04B 9/00, E04F 13/08) ❖ **RECOVERING MECHANICAL ENERGY** (E03G 7/08) ➢ CHARGEABLE MECHANICAL ACCUMULATORS IN VEHICLES (B60K 6/10, 6/30, B60L 50/30)
WASTE MANAGEMENT	❖ **WASTE DISPOSAL** (B09B, B65F) ❖ **TREATMENT OF WASTE** ➢ DISINFECTION OR STERILISATION (A61L 11/00) ➢ TREATMENT OF HAZARDOUS OR TOXIC WASTE (A62D 3/00, 101/00) ➢ TREATING RADIOACTIVELY CONTAMINATED MATERIAL; DECONTAMINATION ARRANGEMENTS THEREFOR (G21F 9/00) ➢ REFUSE SEPARATION (B03B 9/06) ➢ RECLAMATION OF CONTAMINATED SOIL (B09C) ➢ MECHANICAL TREATMENT OF WASTE PAPER (D21B 1/08, 1/32) ❖ **CONSUMING WASTE BY COMBUSTION** (F23G) ❖ **REUSE OF WASTE MATERIALS** ➢ USE OF RUBBER WASTE IN FOOTWEAR (A43B 1/12, 21/14) ➢ MANUFACTURE OF ARTICLES FROM WASTE METAL PARTICLES (B22F 8/00) ➢ PRODUCTION OF HYDRAULIC CEMENTS FROM WASTE MATERIALS (C04B 7/24-7/30) ➢ USE OF WASTE MATERIALS AS FILLERS FOR MORTARS, CONCRETE (C04B 18/04-18/10) ➢ PRODUCTION OF FERTILISERS FROM WASTE OR REFUSE (C05F) ➢ RECOVERY OR WORKING-UP OF WASTE MATERIALS (C08J 11/00-11/28, C09K 11/01, C11B 11/00, 13/00-13/04, C14C 3/32, C21B 3/04, C25C 1/00, D01F 13/00-13/04)

	▪ RECOVERY OF PLASTICS MATERIALS FROM WASTE (B29B 17/00) ▪ DISASSEMBLY OF VEHICLES FOR RECOVERY OF SALVAGEABLE PARTS (B62D 67/00) ▪ OF POLYMERS (C08J 11/04-11/28) ▪ PRODUCTION OF LIQUID HYDROCARBONS FROM RUBBER WASTE (C10G 1/10) ▪ SOLID FUELS DERIVED FROM WASTE (C10L 5/46, 5/48) ▪ OBTAINING METALS FROM SCRAP (C22B 7/00-7/04, 19/30, 25/06) ▪ DISINTEGRATING FIBROUS MATERIALS FOR REUSE (D01G 11/00) ▪ WORKING-UP WASTE PAPER TO OBTAIN CELLULOSE (D21C 5/02) ▪ RECLAIMING SALVAGEABLE COMPONENTS OR MATERIAL FROM ELECTRIC DISCHARGE TUBES OR LAMPS (H01J 9/50, 9/52) ▪ RECLAIMING SERVICEABLE PARTS OF WASTE CELLS, BATTERIES OR ACCUMULATORS (H01M 6/52, 10/54) ❖ **POLLUTION CONTROL** ➢ CARBON CAPTURE AND STORAGE (B01D 53/14, 53/22, 53/62, B65G 5/00, C01B 32/50, E21B 41/00, 43/16, E21F 17/16, F25J 3/02) ➢ AIR QUALITY MANAGEMENT ▪ TREATMENT OF WASTE GASES (B01D 53/00-53/96) • EXHAUST APPARATUS FOR COMBUSTION ENGINES WITH MEANS FOR TREATING EXHAUST (F01N 3/00-3/38) • RENDERING EXHAUST GASES INNOCUOUS (B01D 53/92, F02B 75/10) • REMOVAL OF WASTE GASES OR DUST IN STEEL PRODUCTION (C21C 5/38) • COMBUSTION APPARATUS USING RECIRCULATION OF FLUE GASES (C10B 21/18, F23B 80/02, F23C 9/00) • COMBUSTION OF WASTE GASES OR NOXIOUS GASES (F23G 7/06) • ELECTRICAL CONTROL OF EXHAUST GAS TREATING APPARATUS (F01N 9/00) ▪ SEPARATING DISPERSED PARTICLES FROM GASES OR VAPOURS (B01D 45/00-51/00, B03C 3/00) • DUST REMOVAL FROM FURNACES (C21B 7/22, C21C 5/38, F27B 1/18, F27B 15/12) ▪ USE OF ADDITIVES IN FUELS OR FIRES TO REDUCE SMOKE OR FACILITATE SOOT REMOVAL (C10L 10/02, 10/06, F23J 7/00) ▪ ARRANGEMENTS OF DEVICES FOR TREATING SMOKE OR FUMES FROM COMBUSTION APPARATUS (F23J 15/00) ▪ DUST-LAYING OR DUST-ABSORBING MATERIALS (C09K 3/22) ▪ POLLUTION ALARMS (G08B 21/12) ➢ CONTROL OF WATER POLLUTION ▪ TREATING WASTE-WATER OR SEWAGE (B63J 4/00, C02F) • TO PRODUCE FERTILISERS (C05F 7/00) ▪ MATERIALS FOR TREATING LIQUID POLLUTANTS (C09K 3/32) ▪ REMOVING POLLUTANTS FROM OPEN WATER (B63B 35/32, E02B 15/04) ▪ PLUMBING INSTALLATIONS FOR WASTE WATER (E03C 1/12) ▪ MANAGEMENT OF SEWAGE (C02F 1/00, 3/00, 9/00, E03F) ➢ MEANS FOR PREVENTING RADIOACTIVE CONTAMINATION IN THE EVENT OF REACTOR LEAKAGE (G21C 13/10)
AGRICULTURE/ FORESTRY	❖ **FORESTRY TECHNIQUES** (A01G 23/00) ❖ **ALTERNATIVE IRRIGATION TECHNIQUES** (A01G 25/00) ❖ **PESTICIDE ALTERNATIVES** (A01N 25/00-65/00) ❖ **SOIL IMPROVEMENT** (C09K 17/00, E02D 3/00) ➢ ORGANIC FERTILISERS DERIVED FROM WASTE (C05F)
ADMINISTRATIVE, REGULATORY OR DESIGN ASPECTS	❖ **COMMUTING (E.G., HOV, TELEWORKING, ETC.)** (G06Q, G08G) ❖ **CARBON/EMISSIONS TRADING (E.G. POLLUTION CREDITS)** (G06Q) ❖ **STATIC STRUCTURE DESIGN** (E04H 1/00)

NUCLEAR POWER GENERATION	❖ **NUCLEAR ENGINEERING** (G21) ➢ FUSION REACTORS (G21B) ➢ NUCLEAR (FISSION) REACTORS (G21C) ➢ NUCLEAR POWER PLANT (G21D) ❖ **GAS TURBINE POWER PLANTS USING HEAT SOURCE OF NUCLEAR ORIGIN** (F02C 1/05)

APPENDIX 2: Y02 – EPO classification scheme

Source:https://www.epo.org/news-events/in-focus/classification/classification/updatesYO2andY04S.html

SECTION	TITLE
Y02A TECHNOLOGIES FOR ADAPTATION TO CLIMATE CHANGE	❖ **AT COASTAL ZONES; AT RIVER BASINS** (Y02A 10/00) ❖ **WATER CONSERVATION; EFFICIENT WATER SUPPLY; EFFICIENT WATER USE** (Y02A 20/00) ❖ **ADAPTING OR PROTECTING INFRASTRUCTURE OR THEIR OPERATION** (Y02A 30/00) ❖ **ADAPTATION TECHNOLOGIES IN AGRICULTURE, FORESTRY, LIVESTOCK OR AGROALIMENTARY PRODUCTION** (Y02A 40/00) ❖ **IN HUMAN HEALTH PROTECTION, E.G. AGAINST EXTREME WEATHER** (Y02A 50/00) ❖ **TECHNOLOGIES HAVING AN INDIRECT CONTRIBUTION TO ADAPTATION TO CLIMATE CHANGE** (Y02A 90/00)
Y02B CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS, INCLUDING HOUSING AND ELECTRICAL APPLIANCES OR RELATED END-USER APPLICATIONS	❖ **INTEGRATION OF RENEWABLE ENERGY SOURCES IN BUILDINGS** (Y02B 10/00) ❖ **ENERGY EFFICIENT LIGHTING TECHNOLOGIES, E.G. HALOGEN LAMPS OR GAS DISCHARGE LAMPS** (Y02B 20/00) ❖ **ENERGY EFFICIENT HEATING, VENTILATION OR AIR CONDITIONING [HVAC]** (Y02B 30/00) ❖ **TECHNOLOGIES AIMING AT IMPROVING THE EFFICIENCY OF HOME APPLIANCES, E.G. INDUCTION COOKING OR EFFICIENT TECHNOLOGIES FOR REFRIGERATORS, FREEZERS OR DISH WASHERS** (Y02B 40/00) ❖ **ENERGY EFFICIENT TECHNOLOGIES IN ELEVATORS, ESCALATORS AND MOVING WALKWAYS, E.G. ENERGY SAVING OR RECUPERATION TECHNOLOGIES** (Y02B 50/00) ❖ **TECHNOLOGIES FOR AN EFFICIENT END-USER SIDE ELECTRIC POWER MANAGEMENT AND CONSUMPTION** (Y02B 70/00) ❖ **ARCHITECTURAL OR CONSTRUCTIONAL ELEMENTS IMPROVING THE THERMAL PERFORMANCE OF BUILDINGS**

	(Y02B 80/00) ❖ **ENABLING TECHNOLOGIES OR TECHNOLOGIES WITH A POTENTIAL OR INDIRECT CONTRIBUTION TO GHG EMISSIONS MITIGATION** (Y02B 90/00)
Y02C CAPTURE, STORAGE, SEQUESTRATION, OR DISPOSAL OF GREENHOUSE GASES	❖ **CAPTURE OR DISPOSAL OF GREENHOUSE GASES** (Y02C 20/00)
Y02D ICT THAT AIMS TO REDUCE ITS OWN ENERGY CONSUMPTION	❖ **ENERGY EFFICIENT COMPUTING, E.G. LOW POWER PROCESSORS, POWER MANAGEMENT OR THERMAL MANAGEMENT** (Y02D 10/00) ❖ **REDUCING ENERGY CONSUMPTION IN COMMUNICATION NETWORKS** (Y02D 30/00)
Y02E CLIMATE CHANGE MITIGATION TECHNOLOGIES IN POWER GENERATION, TRANSMISSION AND DISTRIBUTION	❖ **ENERGY GENERATION THROUGH RENEWABLE ENERGY SOURCES** (Y02E 10/00) ❖ **COMBUSTION TECHNOLOGIES WITH MITIGATION POTENTIAL** (Y02E 20/00) ❖ **ENERGY GENERATION OF NUCLEAR ORIGIN** (Y02E 30/00) ❖ **TECHNOLOGIES FOR AN EFFICIENT ELECTRICAL POWER GENERATION, TRANSMISSION OR DISTRIBUTION** (Y02E 40/00) ❖ **TECHNOLOGIES FOR THE PRODUCTION OF FUEL OF NON-FOSSIL ORIGIN** (Y02E 50/00) ❖ **ENABLING TECHNOLOGIES; TECHNOLOGIES WITH A POTENTIAL OR INDIRECT CONTRIBUTION TO GHG EMISSIONS MITIGATION** (Y02E 60/00) ❖ **OTHER ENERGY CONVERSION OR MANAGEMENT SYSTEMS REDUCING GHG EMISSIONS** (Y02E 70/00)
Y02P CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR MANUFACTURING OF GOODS	❖ **TECHNOLOGIES RELATED TO METAL PROCESSING** (Y02P 10/00) ❖ **TECHNOLOGIES RELATING TO CHEMICAL INDUSTRY** (Y02P 20/00) ❖ **TECHNOLOGIES RELATING TO OIL REFINING AND PETROCHEMICAL INDUSTRY** (Y02P 30/00) ❖ **TECHNOLOGIES RELATING TO THE PROCESSING OF MINERALS** (Y02P 40/00)

	❖ **TECHNOLOGIES RELATING TO AGRICULTURE, LIVESTOCK OR AGROALIMENTARY INDUSTRIES** (Y02P 60/00) ❖ **CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION PROCESS FOR FINAL INDUSTRIAL OR CONSUMER PRODUCTS** (Y02P 70/00) ❖ **CLIMATE CHANGE MITIGATION TECHNOLOGIES FOR SECTOR-WIDE APPLICATIONS** (Y02P 80/00) ❖ **ENABLING TECHNOLOGIES WITH A POTENTIAL CONTRIBUTION TO GREENHOUSE GAS [GHG] EMISSIONS MITIGATION** (Y02P 90/00)
Y02T TRANSPORTATION-RELATED CLIMATE CHANGE MITIGATION TECHNOLOGIES	❖ **ROAD TRANSPORT OF GOODS OR PASSENGERS** (Y02T 10/00) ❖ **TRANSPORTATION OF GOODS OR PASSENGERS VIA RAILWAYS, E.G. ENERGY RECOVERY OR REDUCING AIR RESISTANCE** (Y02T 30/00) ❖ **AERONAUTICS OR AIR TRANSPORT** (Y02T50/00) ❖ **MARITIME OR WATERWAYS TRANSPORT (**Y02T 70/00) ❖ **ENABLING TECHNOLOGIES OR TECHNOLOGIES WITH A POTENTIAL OR INDIRECT CONTRIBUTION TO GHG EMISSIONS MITIGATION** (Y02T 90/00)
Y02W CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO WASTEWATER TREATMENT OR WASTE MANAGEMENT	❖ **TECHNOLOGIES FOR WASTEWATER TREATMENT** (Y02W 10/00) ❖ **TECHNOLOGIES FOR SOLID WASTE MANAGEMENT** (Y02W 30/00) ❖ **ENABLING TECHNOLOGIES OR TECHNOLOGIES WITH A POTENTIAL OR INDIRECT CONTRIBUTION TO GREENHOUSE GAS [GHG] EMISSIONS MITIGATION** (Y02W 90/00)

APPENDIX 3: IPC Green Inventory Final Search Queries

TOPIC	QUERY
ALTERNATIVE ENERGY PRODUCTION	IC=(A01H OR A62D000302 OR B01D005302 OR B01D005314 OR B01D005322 OR B01D005324 OR B09B OR B63B003500 OR B63H001902 OR B63H001904 OR B63H001300 OR B60K001600 OR B60L000800 OR C02F000116 OR C07C006700 OR C07C006900 OR C10B005302 OR C10B005300 OR C01B003302 OR C21B000506 OR C30B002906 OR C10G OR C10L000100 OR C10L000300 OR C10L000500 OR C10L000900 OR C10J OR C11C000310 OR C23C001414 OR C23C001624 OR C12P000706 OR C12P000502 OR C12P0007649 OR C12N000113 OR C12N000115 OR C12N000121 OR C12N000924 OR C12N000510 OR C12N001500 OR C02F000114 OR C02F001104 OR C02F001114 OR C02F000328 OR C12M0001107 OR D21C001100 OR D21F000520 OR E02B000900 OR E04H001200 OR E04D001300 OR F01K OR F01N000500 OR F02C000328 OR F02C000105 OR F02C000618 OR F03B OR F03C OR F03D OR F02G000500 OR F23B009000 OR F03G000400 OR F03G000500 OR F03G000600 OR F03G000704 OR F23G000500 OR F23G000700 OR F22B000100 OR F25B002700 OR F25B003000 OR F26B000300 OR F21L000400 OR F21S000903 OR F24S OR F24D001700 OR F24D001100 OR F24D000300 OR F24D000500 OR F24D001900 OR F24D001504 OR F27D001700 OR F24F000500 OR F24F001200 OR F24H000400 OR F24V003000 OR F24V004000 OR F24V005000 OR F24T OR F28D001700 OR F28D001900 OR F28D002000 OR G02B0007183 OR G05F000167 OR H01G000920 OR H01L002500 OR H01L003100 OR H01L002730 OR H01L0027142 OR H01L005142 OR H01M000800 OR H01M001200 OR H01M000486 OR H02J000735 OR H02K000718 OR H02S OR H02N001000) AND ALL=((environment* NEAR2 friend) OR renewable OR "green energy" OR (energy NEAR2 saving) OR ecolog* OR pollut*) AND AY>=(2015) AND CC=(EP)
TRANSPORTATION	IC=(B60K000600 OR B60K001600 OR B60L000710 OR B60L000720 OR B60L000722 OR B60L000800 OR B60L000900 OR B60L005050 OR B60L005090 OR B60W002000 OR B61 OR B62D003500 OR B62K OR B62M000100 OR B62M000300 OR B62M000500 OR B62M000600 OR B63B000134 OR B63B000136 OR B63B000140 OR B63H000900 OR B63H001300 OR B63H001902 OR B63H001600 OR B63H002118 OR B64G000144 OR F02B004300 OR F02M002102 OR F02M002702 OR F16H000300 OR F16H004800 OR H02K002908 OR H02K004910 OR H02J000700) AND ALL=((environment* NEAR2 friend) OR renewable OR "green energy" OR (energy NEAR2 saving) OR ecolog* OR pollut*) AND AY>=(2015) AND CC=(EP)
ENERGY CONSERVATION	IC=(B60K000628 OR B60K000610 OR B60K000630 OR B60L000300 OR B60L005030 OR B60W001026 OR C09K000500 OR H01M001044 OR H01M001046 OR

	H01G001100 OR H01L003300 OR H01L005150 OR H02J OR H05B003300 OR G01R OR F24H000700 OR F28D002000 OR F21K009900 OR F21L000402 OR E04B000162 OR E04B000200 OR E04B000500 OR E04B000700 OR E04B000900 OR E04C000140 OR E04C0002284 OR E06B0003263 OR E04F001308 OR E04F001518 OR E04D000128 OR E04D000335 OR E04D001316 OR F03G000708) AND ALL=((environment* NEAR2 friend) OR renewable OR "green energy" OR (energy NEAR2 saving) OR ecolog* OR pollut*) AND AY>=(2015) AND CC=(EP)
WASTE MANAGEMENT	IC=(A43B000112 OR A43B002114 OR A61L001100 OR A62D000300 OR A62D010100 OR B01D004500 OR B01D004600 OR B01D004700 OR B01D004900 OR B01D005000 OR B01D005100 OR B01D005300 OR B03B000906 OR B03C000300 OR B09B OR B09C OR B22F000800 OR B29B001700 OR B62D006700 OR B63B003532 OR B63J000400 OR B65F OR B65G000500 OR C01B003250 OR C02F OR C04B000724 OR C04B001804 OR C05F OR C08J001100 OR C09K000332 OR C09K000322 OR C09K001101 OR C10B002118 OR C10G000110 OR C10L001002 OR C10L001006 OR C10L000546 OR C10L000548 OR C11B001100 OR C11B001300 OR C14C000332 OR C21B000722 OR C21B000304 OR C21C000538 OR C22B000700 OR C22B001930 OR C22B002506 OR C25C000100 OR D01G001100 OR D01F001300 OR D21B000108 OR D21B000132 OR D21C000502 OR E02B001504 OR E03C000112 OR E03F OR E21B004100 OR E21B004316 OR E21F001716 OR F01N000900 OR F01N000300 OR F02B007510 OR F23B008002 OR F23C000900 OR F23G OR F23J000700 OR F23J001500 OR F25J000302 OR F27B000118 OR F27B001512 OR G08B002112 OR G21C001310 OR G21F000900 OR H01J000950 OR H01J000952 OR H01M000652 OR H01M001054) AND ALL=((environment* NEAR2 friend) OR renewable OR "green energy" OR (energy NEAR2 saving) OR ecolog* OR pollut*) AND AY>=(2015) AND CC=(EP)
AGRICULTURE/FORESTRY	IC=(A01G002300 OR A01G002500 OR A01N002500 OR A01N002700 OR A01N002900 OR A01N003100 OR A01N003300 OR A01N003500 OR A01N003700 OR A01N003900 OR A01N004100 OR A01N004300 OR A01N004500 OR A01N004700 OR A01N004900 OR A01N005100 OR A01N005300 OR A01N005500 OR A01N005700 OR A01N005900 OR A01N006100 OR A01N006300 OR A01N006500 OR C05F OR C09K001700 OR E02D000300) AND ALL=((environment* NEAR2 friend) OR renewable OR "green energy" OR (energy NEAR2 saving) OR ecolog* OR pollut*) AND AY>=(2015) AND CC=(EP)
ADMINISTRATIVE, REGULATORY OR DESIGN ASPECTS	IC=(G06Q OR G08G OR E04H000100) AND ALL=((environment* NEAR2 friend) OR renewable OR "green energy" OR (energy NEAR2 saving) OR ecolog* OR pollut*) AND AY>=(2015) AND CC=(EP)
NUCLEAR POWER GENERATION	IC=(G21 OR F02C000105) AND ALL=((environment* NEAR2 friend) OR renewable OR "green energy" OR (energy NEAR2 saving) OR ecolog* OR pollut*) AND AY>=(2015) AND CC=(EP)

APPENDIX 4: Y02 (EPO) Final Search Queries

GROUP	QUERY
Y02A	ACP=(Y02A) AND AY>=(2015) AND CC=(EP)
Y02B	ACP=(Y02B) AND AY>=(2015) AND CC=(EP)
Y02C	ACP=(Y02C) AND AY>=(2015) AND CC=(EP)
Y02D	ACP=(Y02D) AND AY>=(2015) AND CC=(EP)
Y02E	ACP=(Y02E) AND AY>=(2015) AND CC=(EP)
Y02P	ACP=(Y02P) AND AY>=(2015) AND CC=(EP)
Y02T	ACP=(Y02T) AND AY>=(2015) AND CC=(EP)
Y02W	ACP=(Y02W) AND AY>=(2015) AND CC=(EP)