THE GEOGRAPHY OF MADE IN ITALY ECO-INNOVATION

green patents

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0.0.

INTRO-DUCTION

> For too long, we have inadequately addressed the issue of environmental protection and climate change, artificially pitting the reasons for managing the present against those for managing the future of our children and grandchildren. To ensure its competitiveness, Europe needs to abandon fossil fuels in the long term and make the transition, highlighting the link between decarbonisation and competitiveness.
>
> **Sergio Mattarella**

In the call by the President of the Republic, Sergio Mattarella, not to pit 'management of the existing situation against management of the future', technological innovation is confirmed as a decisive factor in bringing together ecological transition and competitiveness. Mapping solutions that reduce emissions, increasing energy efficiency, accelerating electrification and supporting renewable sources does not only mean providing a litmus test of the country's innovative capacity, it also means understanding what concrete and new tools we have at our disposal today in the process of decarbonisation and industrial transformation.

The study *The geography of Made in Italy eco-innovation*, carried out jointly by Fondazione Symbola and Unioncamere, in collaboration with Dintec and Centro Studi Guglielmo Tagliacarne, while it does not portray the full wealth of Italian eco-innovation, anyhow offers valuable insights into the sectors and territories where innovation is concentrated and allows us to explore the link between green innovation and competitiveness[0] through the analysis of green patents.

In this context, Italy ranks among the top three European countries in terms of the number of green patents and is also third in terms of the share of companies with patents out of the total number of companies (16.5 per 1,000 companies), after Germany (21.6) and Austria (18.9). This is an important figure that underestimates the dynamism of the production system, where investment in sustainability is constantly growing and where 578,450 companies have made eco-investments between 2019 and 2024 (38.7% of the total).[1] Widespread innovation is not always translated into intellectual property rights,

0 A comprehensive view should also include all innovation that is not patented or protected by other intellectual property rights, such as trade secrets that are made available to the community in the context of open science, or simply not protected.

1 Fondazione Symbola, Unioncamere, Centro Studi Tagliacarne, GreenItaly, 2025.

partly because of an industrial culture that is still not much oriented towards the systematic exploitation of research and development results.

In many cases, Italian companies choose to protect their innovations by resorting to trade secrets rather than patenting. It is no coincidence that Italy is among the European countries where the use of proprietary know-how is most widespread: between 2017 and 2022, according to EUIPO data, as many as 151 legal proceedings were initiated in relation to the violation of trade secrets, a number that far exceeds that recorded in economies such as Germany, France and Spain.[2] This preference can be partly explained by the structure of our production fabric, which is strongly characterised by small and medium-sized enterprises, but it has its limitations. Trade secrets are an effective means of protection when there is certainty that technical and industrial information is difficult to obtain, not generally known to experts in the field and not easily subject to reverse engineering. However, its protection requires the adoption of complex organisational measures: identification and classification of the information to be protected; implementation of security procedures for both personnel and data access; preparation of legal instruments such as confidentiality agreements with employees, contract workers and third parties. On the contrary, trade secrets offer no protection against competitors who, through independent research or lawful reverse engineering, can replicate the solutions developed. In such situations, patents allow companies to consolidate their competitive advantage and maintain a lasting presence in new technological areas, offering specific and exclusive protection in the field of technical inventions.

2 Source: *Trade Secrets Litigation Trends in the EU,* European Union Intellectual Property Office, 2023.

In Italy, between 2017 and 2022, 151 proceedings relating to trade secrets were recorded. Almost all of these took place before courts specialising in intellectual property (92%) and were brought as civil cases, with a small proportion (4%) as criminal cases. The appeal rate was relatively low (11%, compared to an EU average of 46%), while the success rate of infringement actions was higher than the European average: 41% in Italy compared to 27% in the EU. As for the profiles of the parties, 46% of the plaintiffs were SMEs, 20% were micro-enterprises and 21% were large companies; among the defendants, 35% were former employees, 24% were SMEs and 19% were micro-enterprises. Relationships between the parties were often absent (45% of cases), but there were also former employment relationships (26%) and commercial partnerships (24%). In 87% of proceedings, all parties were Italian; only 8% involved other EU countries and 5% involved non-EU countries. In terms of the information protected, 53% of the secrets concerned commercial data (in particular downstream information, 34%) and 40% concerned technical aspects (primarily production processes, 24%). The sector most involved was manufacturing (59%), followed by financial and insurance services (10%).

Despite these critical issues, Italy holds important patents in key sectors: sustainable mobility, where Italian patents account for 31% of the total number of patents relating to climate change mitigation; energy efficiency in construction, where we exceed the EU average; waste and wastewater management, a sector in which we are traditionally among the most dynamic countries; and ICT technologies for climate mitigation, with a record increase of +270% over the last ten years.

The northern regions – Lombardy, Emilia-Romagna, Veneto and Piedmont – are driving this trend thanks to their manufacturing tradition and their ability to transform research and industrial know-how into concrete solutions.

Businesses are the main players, accounting for 81.9% of published applications, followed by individuals (12.9%), while institutions account for 5.2%.

An analysis of the sectoral distribution of Italian European patent applications in the green sector confirms that manufacturing is the main driver of innovation, followed by sectors related to scientific research (18.8%), telecommunications and IT (6.6%), wholesale trade (3.5%) and construction (3.5%).

Looking at the technological areas, there is a strong presence of solutions related to the digitalisation of production processes and the efficient management of energy and environmental resources (12.0%). These are a set of innovations that contribute to sustainability by improving the efficiency of internal processes and reducing consumption, waste and emissions. This is followed by technologies for measuring and testing electrical and magnetic variables (7.3%), which are crucial solutions for ensuring high energy performance and accurate control of electrical infrastructure. The third most

important area is technologies for the treatment of wastewater, sewage and sludge (6.5%). This sector confirms the centrality of sustainable water management policies, which are increasingly strategic within a context of growing attention to environmental protection. This is followed by technologies related to bicycles and micro-mobility vehicles, concerning frames, steering systems, suspensions and various devices that make these vehicles increasingly efficient and competitive. The fifth area is energy, which includes solutions for alternating or direct current distribution networks, battery management and charging systems, multi-source power supply and even technologies for wireless energy transmission.

The study also highlights the link between green innovation and competitiveness. Italian companies that file patents in green technologies are significantly more competitive than those that patent in other (non-green) areas. They generate much higher turnover per company (€382 million per company compared to €41 million per non-green companies) and record higher productivity (€144,000 added value per employee compared to €92,000). In terms of exports, more than half (57.8%) export, generating over €63 billion, with a strong diversification of reference markets. In addition, human capital is more highly qualified, with a higher proportion of graduates (29.7%, of which 16.7% in STEMplus disciplines[3]). Finally, these companies attract more foreign capital: 41.9% have foreign shareholdings compared to 31.7% of non-green companies.

Although Italy has demonstrated its ability to innovate and compete in environmental sectors, it needs to take a leap forward: it is necessary to invest more in research, support patenting capacity (even for those who do not currently do so), strengthen technology transfer and replicate the successful model of the circular economy in the fields of efficiency, electrification and renewables. Only in this way will the country be able not only to defend its position but also to aspire to be a leader in European green innovation.

After all, the inspiration for the title of this work comes from Article 9 of the Italian Constitution, which Carlo Azeglio Ciampi described as the most original part of our constitutional system: a unique article because it brings together culture, historical and artistic heritage, scientific and technical research, and, more recently, environmental protection. The result is a project for Italy that, in a time marked by strife, economic competition and clashes between worlds, can offer us a kind of 'insurance' for the future, provided we continue consistently along this path.

Ermete Realacci, President of Fondazione Symbola
Andrea Prete, President of Unioncamere

3 STEM stands for Science, Technology, Engineering and Mathematics and represents an interdisciplinary educational field. The term 'plus' refers to economics and statistics.

chap. 1

TECHNOLOGICAL INNOVATION FOR THE ITALIAN AND EUROPEAN GREEN TRANSITION

This chapter provides an analysis of data updated to 2022, examining the spread of green patents in EU countries, their incidence on total patents, per capita distribution and breakdown into technological subcategories, with the aim of identifying strategic areas for the European Green Deal. Patent activity, as highlighted in the maps in this chapter, tends to be concentrated in specific regions due to self-reinforcing economic, institutional and social mechanisms (knowledge spillover, specialised labour markets, infrastructure, presence of venture capital). Germany emerges as the dominant player, although its position is gradually declining over time. Italy and Spain's shares have increased, suggesting a slow rebalancing.

Italy ranks among the top three European countries in terms of absolute number of environment-related patents, but still has room for improvement in terms of both its share of total patents and its propensity relative to population. However, it shows promising signs in strategic sectors such as environmental management, construction, and sustainable mobility.

The European comparison allows us to identify not only the leading countries but also those that are growing through green specialisation strategies, offering ideas for guiding future policies on innovation and sustainable competitiveness.

1.1.

PATENTING IN THE EUROPEAN UNION

At the end of 2022, approximately 31,000 patents were granted[4] in European Union countries by the European Patent Office,[5] , but not all countries patent in the same way. Three countries – Germany, France and Italy – alone account for 69.5% of the total: Germany leads with 42.2%, followed by France (17.6%) and Italy (9.2%). The German figure is striking, since although it accounts for only 18.7% of the EU population[6], the country generates almost half of European patents, confirming a strong propensity for patenting.

Over the last ten years, European patents have grown by 11.3%, from 27,864 in 2012 to 31,010 in 2022. However, at national level, the dynamics vary: Italy and France both recorded 15.3% in growth, while Germany saw a 4.1% decline.

Among the smaller economies, the Netherlands (+30.8%, from 1,491 to 1,950 patents) and Sweden (+40.6%, from 1,329 to 1,870) stand out, confirming that innovation is gaining ground even outside traditional industrial centres.

4 Patents granted: a patent application does not automatically give the applicant a temporary right against infringement. The patent must be granted in order to be effective and enforceable in the event of infringement.

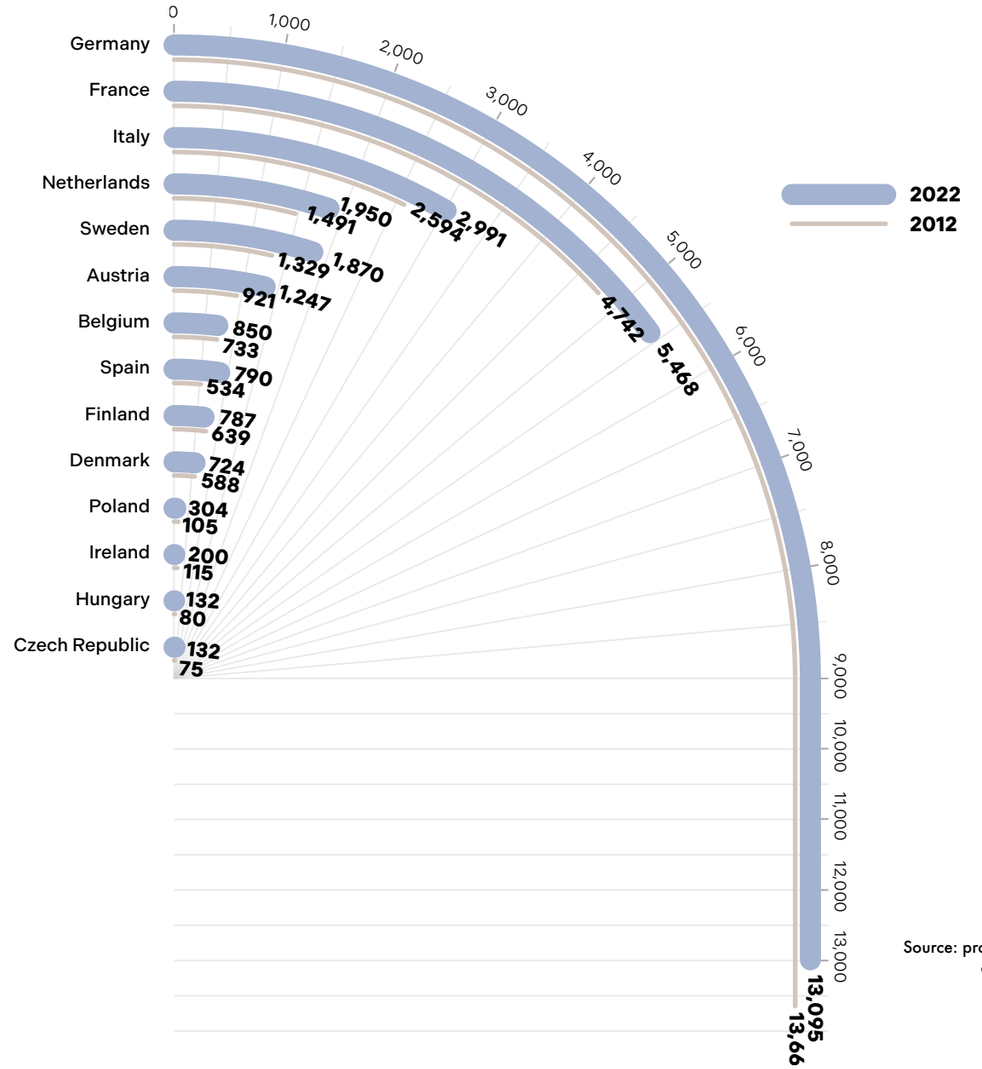
5 The European Patent Office (EPO, a regional patent office) was created by the European Patent Convention (EPC) to grant European patents on the basis of a centralised examination procedure.

6 Eurostat: resident population as at 31 December 2022.

NOTE: In this and subsequent chapters, absolute values are rounded. Percentage changes were calculated on the original values (with decimals) before rounding; for this reason, when recalculating the percentages on the rounded values, the results may not match perfectly.

FIGURE 1

Number of patents (countries with more than 100 patents), 2022

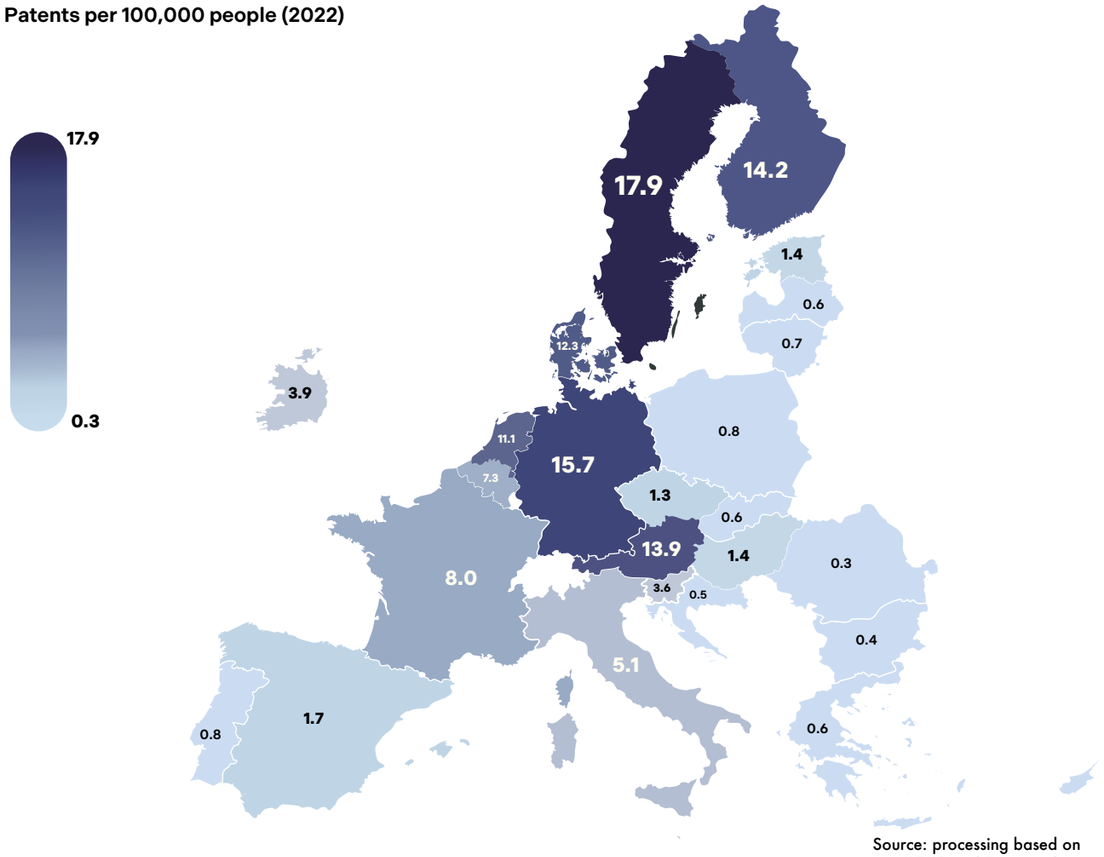


Source: processing based on OECD data

However, other countries are attracting attention, having experienced significant growth in the number of patents over time. Analysing the evolution from 2012 to 2022, Poland, the Czech Republic, Ireland, Hungary and Spain stand out, having recorded the most significant increases compared to their starting point. Poland, especially, has recorded an increase of 189.5%, reaching 304 patents in 2022 and ranking eleventh in Europe, although still greatly removed from Denmark (tenth with 724 patents). The Czech Republic has risen from 75 to 132 patents (+74.9%), Ireland from 115 to 200 (+72.8%) and Hungary from 80 to 132 (+64.9%). Spain also has shown a solid +48%, which has allowed it to climb from tenth to eighth place.

FIGURE 2

Patents per 100,000 people (2022)



Source: processing based on OECD and Eurostat data

However, to assess a country's real innovative capacity, it is useful to compare the number of patents to the population. If we look at patents per 100,000 inhabitants, the picture changes. Sweden leads with 17.9 patents per 100,000 inhabitants, followed by Germany (15.7), Finland (14.2), Austria (13.9) and Denmark (12.3).

Italy, with 5.1 patents per 100,000 inhabitants, ranks tenth and below the EU average (7.0), highlighting a lower propensity for innovation. Despite sustained growth rates, Spain (1.7 patents per 100,000 inhabitants) and Poland (0.8) remain among the least innovative countries in relation to their population, ranking thirteenth and eighteenth, respectively.

The relevance of the Swedish case stands out when comparing these data with the number of patents per 100,000 inhabitants in 2012. This country has in fact gone from 14.0 patents per 100,000 to 17.9, surpassing Germany, which in 2012 was first in terms of propensity to innovate[7]. Furthermore, the Nordic country recorded the greatest change in its propensity between 2012 and 2022 (+3.9 patents per 100,000 residents), followed by Austria (+2.9) and Finland (+2.4), which nevertheless maintained the same positions in the ranking, fourth and third, respectively. In general, however, it can be said that, in terms of propensity, these four countries can be quite rightly considered the 'great innovators' of the European Union that has increased its propensity by +0.7 points compared to 2012, a sign that propensity has not grown in a widespread fashion but rather has concentrated in a group of countries. Within this context, Italy has gone from 4.3 patents to 5.1 per 100,000 inhabitants, growing by +0.8, slightly above the EU-27 average.

7 The term 'propensity to innovate' refers to the intensity of patenting, defined in terms of the number of patents per 100,000 inhabitants.

In addition to analysing granted patents, it is also important to consider the most recent trends in patent applications filed, an indicator that anticipates future technological trajectories. In 2024, the EPO received a total of 199,264 patent applications, a level that remained essentially stable compared to the previous year (-0.1%) despite a macroeconomic environment characterised by uncertainty and slowing growth. Applications from the 39 EPO member countries grew by 0.3% and accounted for 43.3% of the total in 2024, confirming the resilience of European innovation capacity.

In this regard, Germany remains the leading European country of origin for applications, accounting for 12.6% of the total, while other countries show significant growth, particularly Ireland (+4.4%), Switzerland (+3.2%), the United Kingdom (+3.1%), Spain (+3.0%) and Finland (+2.7%). Switzerland also stands out for its higher per capita patent intensity. Bucking the trend, Italy recorded a 4.5% decline in patent applications in 2024, with approximately 4,850 filings, indicating a lower capacity to capture and formalise innovation compared to leading European countries.

Overall, the picture that emerges is one of a solid and attractive European patent system, characterised by strong geographical concentration but also by signs of progressive rebalancing and widespread innovative vitality. The joint analysis of patents granted and applications filed thus provides not only a snapshot of established innovation but also an indication of the directions in which the most recent technological investments are moving, including those related to green technologies and sustainable transition.

1.2.

ENVIRONMENT-RELATED PATENTS

According to the technological classification provided by the OECD, we can group patents into different technologies[8]. This paper investigates a particular type of patent relating to the environment in general, defined by the OECD as environment-related patents[9]. Later in the report, we will see how this category is broken down into various subcategories at different hierarchical levels, allowing us to analyse environment-related patenting from different points of view. Analysing this category, in 2022, 3,990 patents relating to the environment were granted in the European Union. In absolute terms, Germany is the country with the most environment-related patents, with 1,632, followed by France and Italy, with 729 and 295, respectively. The importance of the three major European economies is therefore also evident in environment-related patents, which together account for 66.6% of the total number of environment-related patents in the European Union, even though environment-related patenting seems less concentrated in these three countries compared to total patenting (total share of patents in Germany, France and Italy 69.5%).

If we compare the number of patents to the population (environment-related patents per 1 million inhabitants), a particular patent density emerges in Northern European countries. In fact, the top five positions are held by Denmark (36.8), Sweden (24.4), Finland (19.8), Germany (2.0) and Austria (1.6). Italy, as with its propensity to innovate in terms of total patents, ranks tenth with 5.0 environment-related patents per million inhabitants. In dynamic terms compared to 2012, Sweden and Finland have both

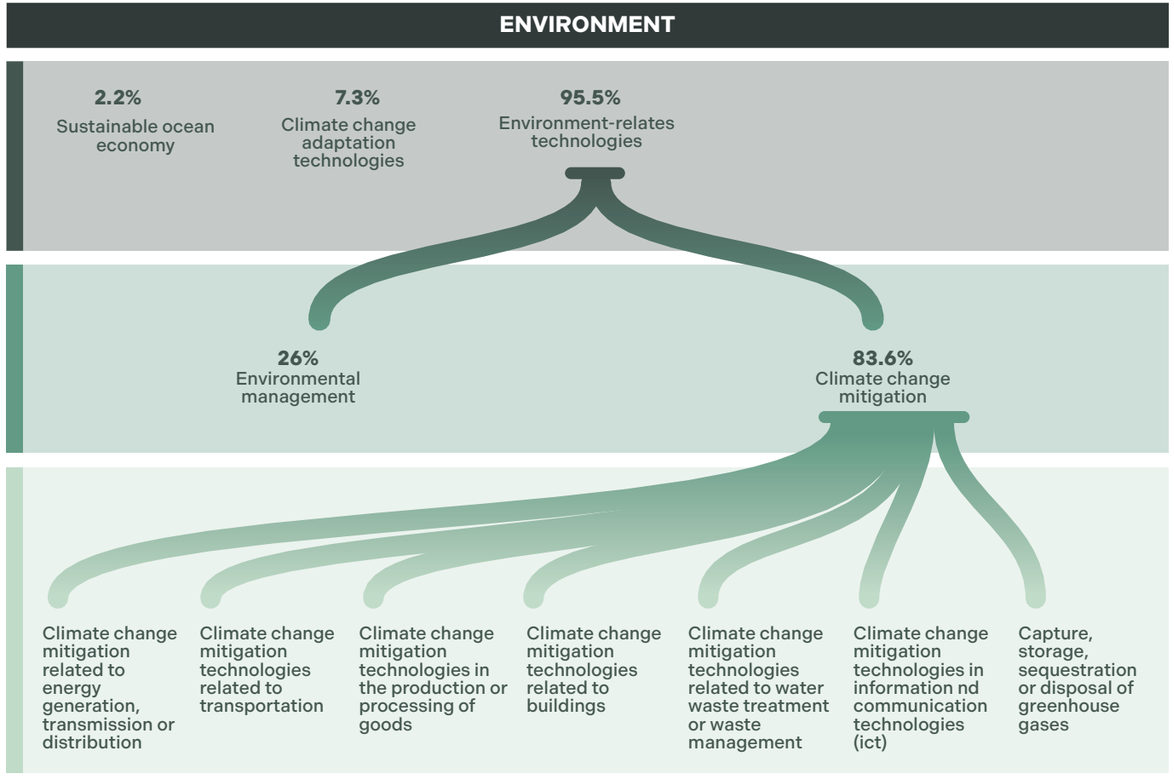
8 Links for further information: Pagina OCSE ; Database documentation ; Environment-related technologies (ENV-TECH), Climate change adaptation technologies, and similar technologies relevant for the ocean economy

9 The OECD's ENV-TECH classification was created to identify patents related to environmental technologies within large international patent databases (such as PATSTAT). It is based on well-defined technical criteria and the IPC (International Patent Classification) codes assigned to patents. Example table: Environmental patents table in EU27 and Italy

FIGURE 3

Hierarchy of OECD environmental technologies[10]

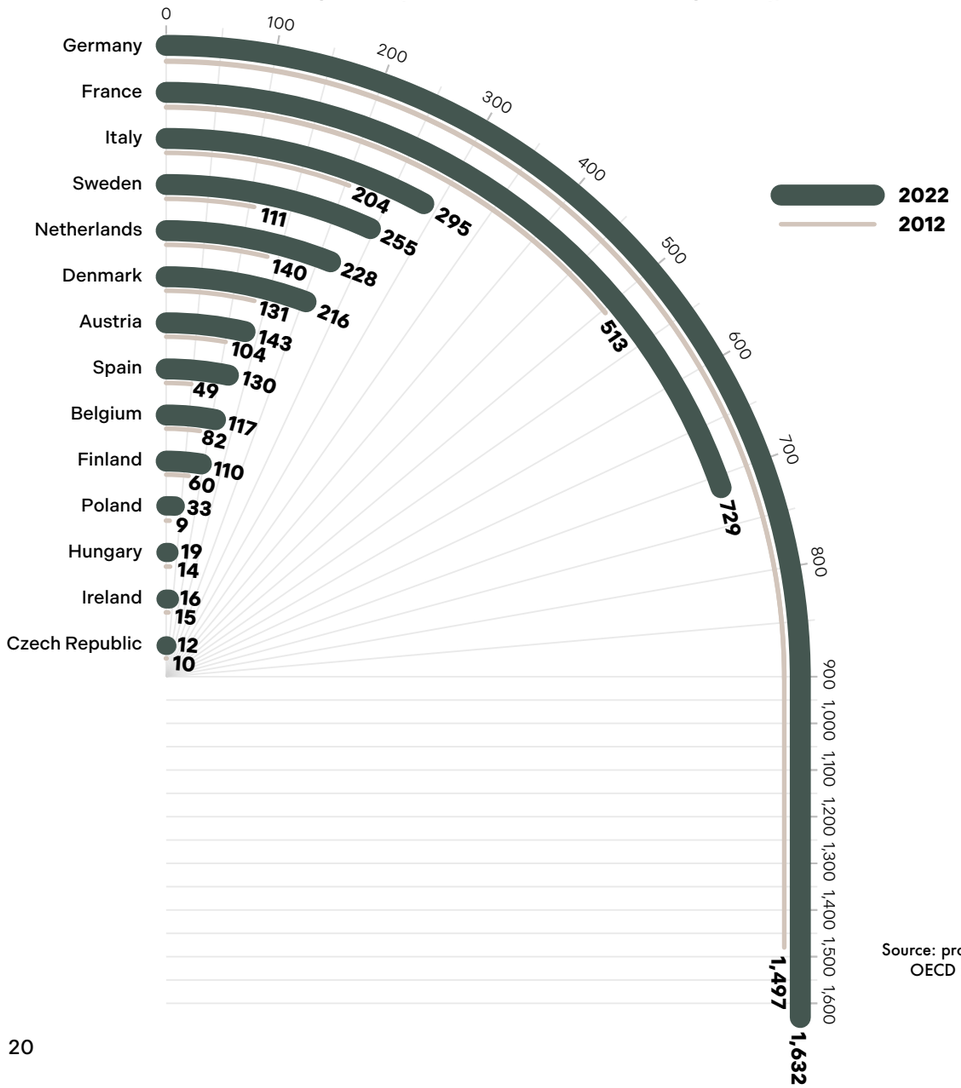
10 For more details, see the appendix A1. The sum of the subcategories does not correspond exactly to the higher hierarchical level because there may be patents (IPC codes) that belong to more than one subcategory.



Source: OECD

FIGURE 4

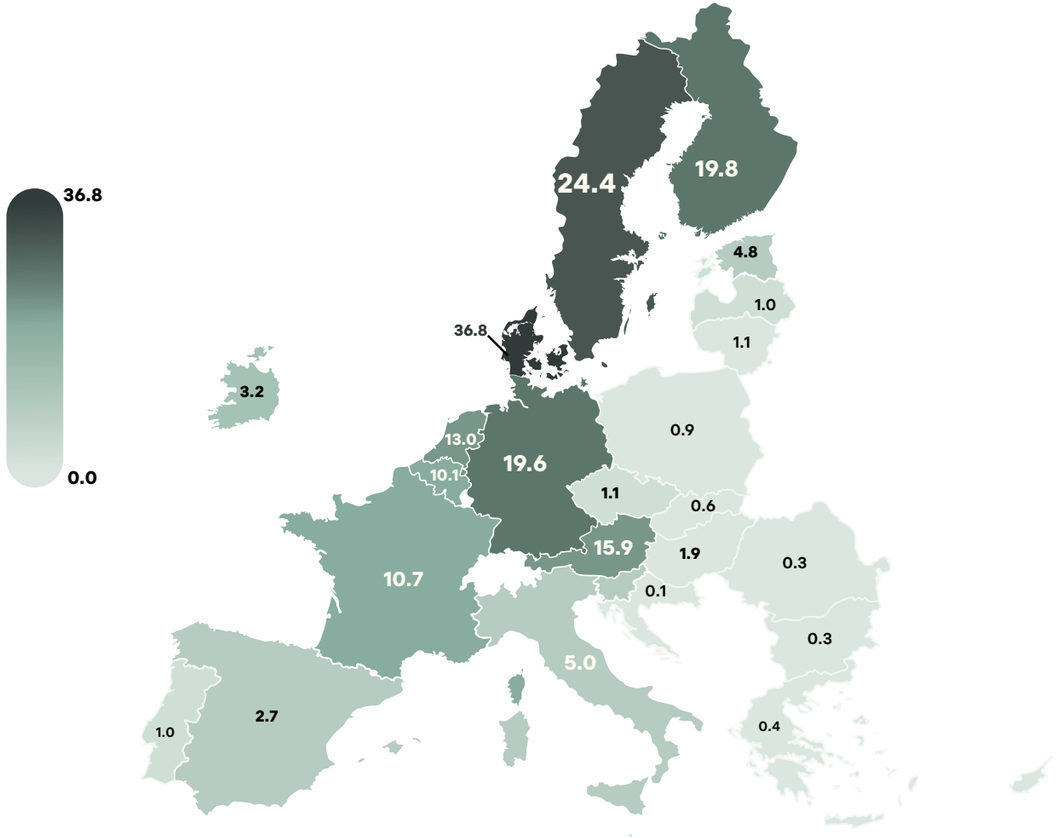
Number of environment-related patents (countries with more than 100 patents), 2022



Source: processing based on OECD and Eurostat data

FIGURE 5

Environment-related patents per 1,000,000 people (2022)



Source: processing based on OECD and Eurostat data

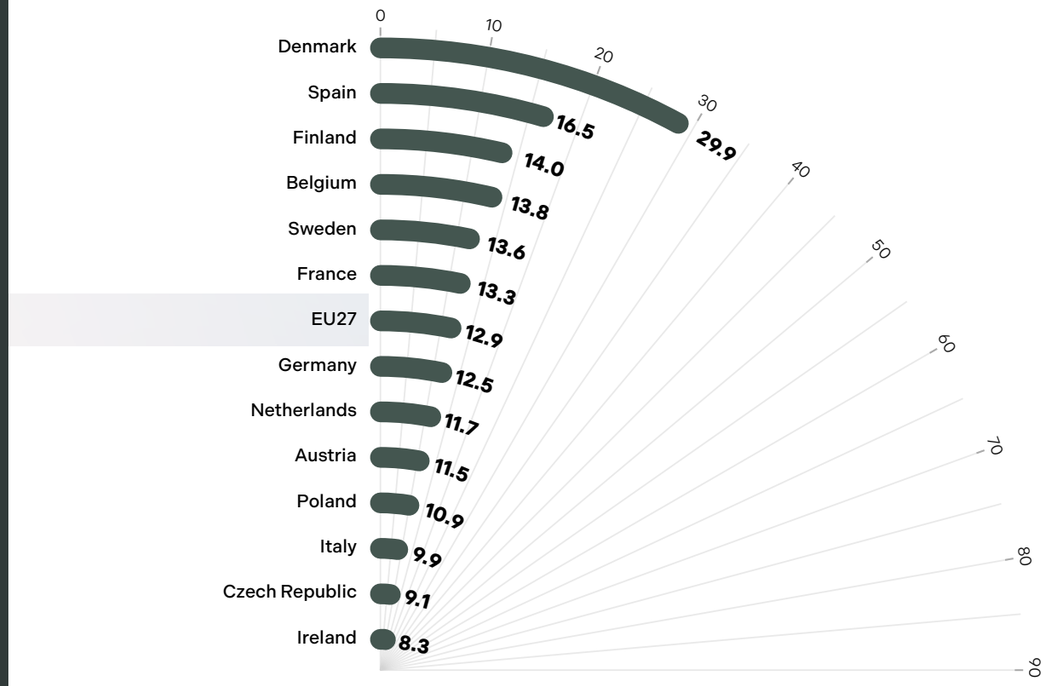
11 The ranking of the share of environment-related patents is calculated for countries with more than 100 patents overall in 2022.

climbed three places in the ranking in terms of propensity for 'green' innovation, ranking second and third, respectively.

With an average incidence of environment-related patents in the European Union of 12.9% of total patents, Denmark remains in first place with 29.9%, followed by Spain (16.5%), Finland (14.0%), Belgium (13.8%) and Sweden (13.6%). Italy ranks eleventh with a share of 9.9%, lower than Germany (12.5%) and France (13.3%).[11]

FIGURE 6

Share of environment-related patents out of total patents (countries with more than 100 patents overall)



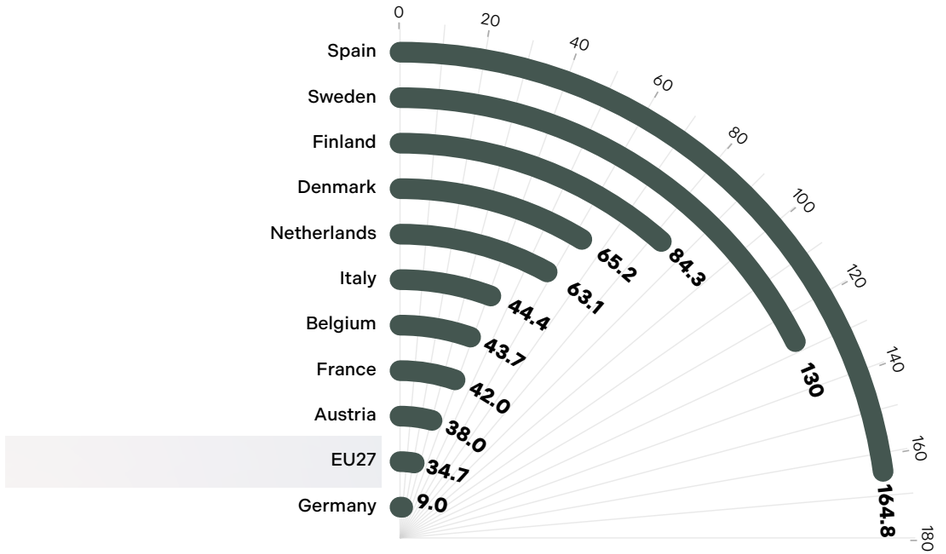
Source: processing based on OECD data

In dynamic terms, Spain showed the highest growth in environment-related patents[12] in the period 2012-2022, equal to 164.8%, rising from 49 to 130 patents, more than Sweden and Finland, which saw the number of environment-related patents increase by 130.0% and 84.3%, respectively. These figures are striking when compared with the 34.7% growth in the rest of the European Union, but even more so when compared with the three major European economies. In fact, Italy recorded a 44.4% growth in 'green' patents, almost similar to France, where it was 42.0%. In contrast, in Germany, the growth in 'green' patents was only 9.0%, lower than the Italian figure and the European average.

12 For this analysis and all subsequent analyses on environment-related patents, only countries with at least 100 environment-related patents granted are considered.

FIGURE 7

Growth in environment-related patents between 2012 and 2022 (countries with more than 100 environment-related patents)

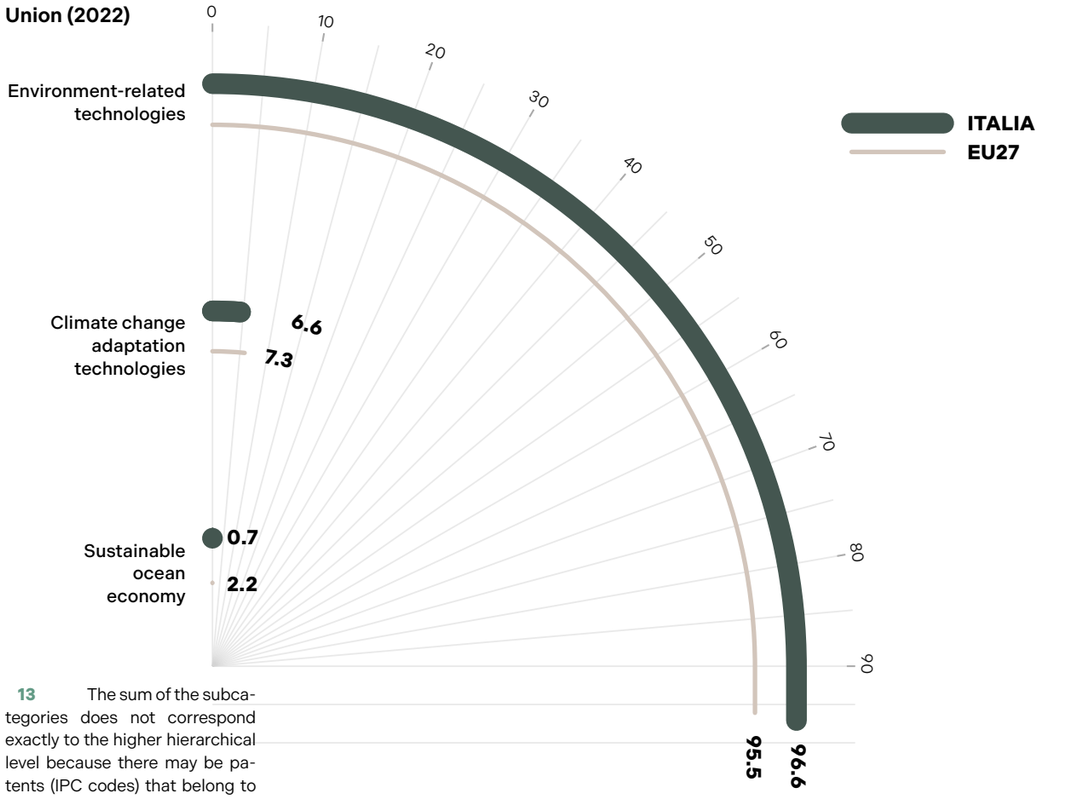


Source: processing based on OECD data

Environment-related patents, in turn, are divided into three subcategories: Environment-related technologies, Climate change adaptation technologies, and Sustainable ocean economy. The first category accounts for 95.5% of EU-27 Environment-related patents, the second for 7.3%, and the last for 2.2%.

FIGURE 8

Share of environment-related patents[13] by category out of total environment-related patents, Italy, European Union (2022)



13 The sum of the subcategories does not correspond exactly to the higher hierarchical level because there may be patents (IPC codes) that belong to more than one subcategory.

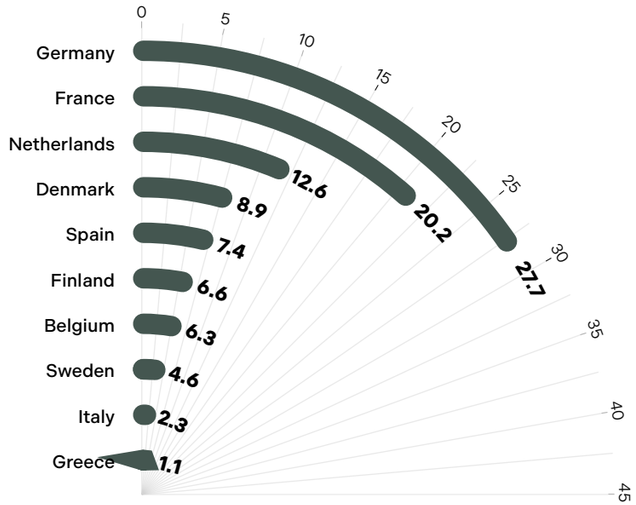
Source: processing based on OECD data

Sustainable ocean economy

The Sustainable ocean economy patents, which are residual compared to the other two categories (2.2% of European environment-related patents), include technologies that promote the sustainable use of marine resources, contributing to the protection of the oceans, responsible fishing, the monitoring of marine ecosystems and the development of alternative marine energy sources, such as wave and tidal energy. In particular, 88 such patents have been registered in the European Union, coming mainly from five countries: Germany (27.7% of EU patents of this type), France (20.2%), the Netherlands (12.6%), Denmark (8.9%) and Spain (7.4%). Together, these five countries account for 76.4% of patents in this category across the entire Union. However, when considering the share of these patents in the total number of environment-related patents, Finland ranks first (5.3%), followed by Spain (5.0%) and the Netherlands (4.8%), while Italy, with a share of 0.7%, ranks below the European average (2.2%) in this respect.

FIGURE 9

Italy's share of patents as a percentage of total patents in the European Union: Sustainable ocean economy (Top 10 countries)



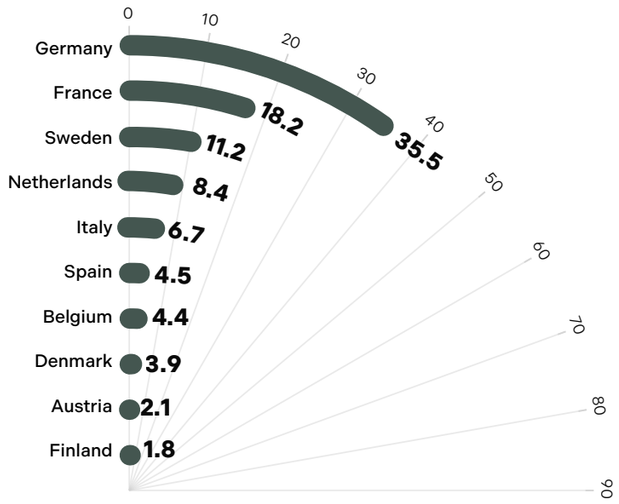
Source: processing based on OECD data

Climate change adaptation technologies

The second category of patents relates to climate change adaptation technologies, which are specific technologies designed to make environments, communities and socio-economic systems more resistant and resilient to the negative effects of climate change. These include measures to reduce exposure to physical risks (such as droughts and floods), improve resilience and preventively manage impacts. This category accounts for 7.3% of the EU's environment-related patents. In Europe, 292 patents have been granted, with Germany holding over a third (35.3%), followed by France (18.2%) and Sweden (11.2%). These three countries together hold 64.7% of EU patents in this category, while Italy ranks fifth with 6.7% of patents issued in the European Union. However, considering the incidence on the total number of environment-related patents issued in each country, Italy ranks below the European average (with 6.6% of patents versus 7.3%), showing a lower propensity than countries such as Sweden (12.8%), Belgium (11.0%) and the Netherlands (10.8%).

FIGURE10

Italy's share of total European Union patents: Climate change adaptation technologies (Top 10 countries)



Source: processing based on OECD data

Environment-related technologies

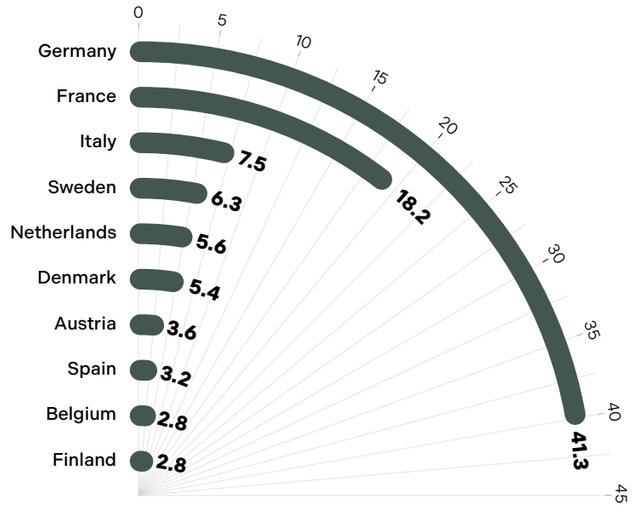
The last category of environment-related patents concerns the so-called *'Environment-related technologies'*[14], which include all technologies that aim to reduce the environmental impact of human activities by improving air, water and soil quality. They include technologies for water, energy and waste management, pollution control and production process efficiency, and energy production from renewable sources. This category, the main one, also accounts for 95.5% of environment-related patents in Europe. In fact, in 2022, 3,810 of these patents were granted in toto, of which 67.0% are concentrated in Germany, France, and Italy, with shares of 41.3%, 18.2%, and 7.5%, respectively. However, if we consider the incidence on the total number of environment-related patents[15], the leading country is Finland, with a share of 97.7%, followed by Italy (96.6%) and Germany (96.5%), while the European incidence is 95.5%.

14 For more details: 'Patent search strategies for the identification of selected environment-related technologies (ENV-TECH), climate change adaptation technologies, and similar technologies relevant for the ocean economy' in:Database documentation.

15 Only countries with at least 100 environment-related patents granted are considered.

FIGURE 11

Italy's share of total European Union patents: Environment-related technologies (Top 10 countries)



Source: processing based on OECD data

1.2.1. ENVIRONMENT-RELATED TECHNOLOGIES

Going into more detail on the subcategories, the category of Environment-related technologies mentioned above can be divided into two subcategories: *Environmental management* (26.0% of EU patents) and *Climate change mitigation* (83.6%). The first division covers all technologies aimed at protecting the environment through the control of air, water and soil pollution, sustainable waste management and monitoring of environmental conditions. In the European Union, 990 *Environmental Management* patents were granted in 2022, 63% of which can be attributed to three countries: Germany, which accounts for almost two-fifths of the total (39.5%), France (13.0%) and Italy (10.8%). It is worth noting that Denmark, which has often ranked among the top countries in other patent categories, ranks last in the top 10 countries, with a 2.6% share of patents related to *environmental management*. Analysing the share of patents related to environmental management out of the total number of environment-related technology patents, compared to an EU27 average of 26.0%, the country with the highest incidence is Finland (39.1%), followed by Italy (37.6%) and Austria (35.2%).

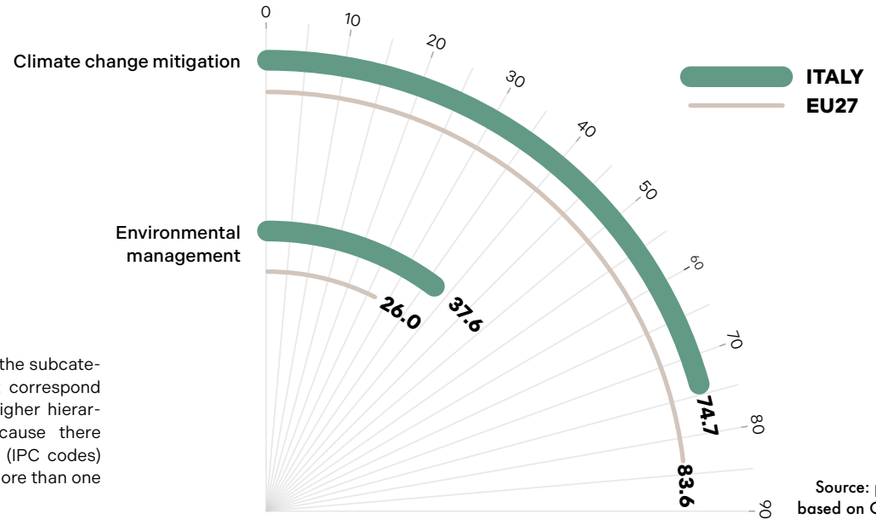
The second subcategory of Environment-related technologies patents is represented by patents for Climate change mitigation, which focuses on technologies developed to control, reduce or prevent anthropogenic greenhouse gas emissions[17].

In 2022, 3,183 patents of this type were granted in the European Union, of which 41.5% were held by Germany, followed by France (19.5%) and Italy (6.7%). These three coun-

17 Links for further information: Environment-related technologies (ENV-TECH), Climate change adaptation technologies, and similar technologies relevant for the ocean economy

FIGURE 12

Share of patents[16] related to environmental management by subcategory out of the total number of environment-related patents, Italy, European Union (2022)

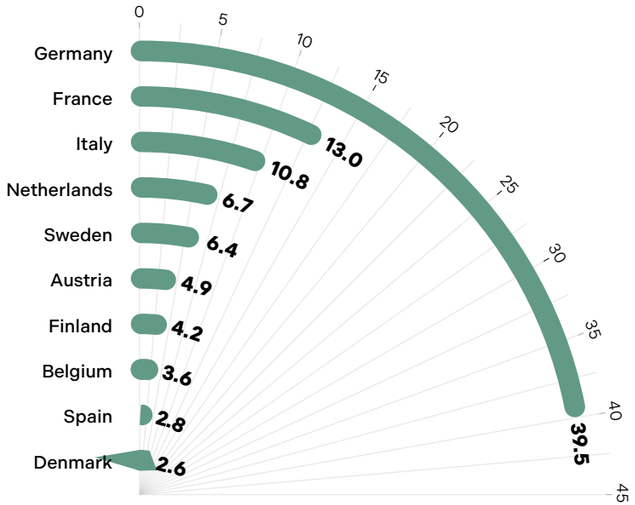


16 The sum of the subcategories does not correspond exactly to the higher hierarchical level because there may be patents (IPC codes) that belong to more than one subcategory.

Source: processing based on OCSE data

FIGURE 13

Italy's share of patents as a percentage of total European Union patents: Environmental management (Top 10 countries)



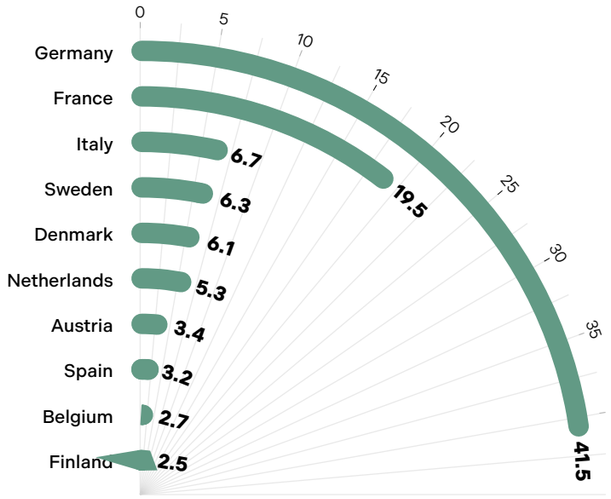
Source: processing based on OECD data

tries account for 67.7% of all patents in this category in the EU. In terms of incidence on the total number of environment-related technologies patents, Denmark ranks first with a share of 93.7%, followed by France (89.6%) and Spain, while Italy has an average incidence well below the EU average (74.7% compared to 83.6%).

This last category also deserves separate consideration, as it is the category with the highest number of environment-related patents and has an additional hierarchical level that allows us to refine our analysis of 'green' patenting.

FIGURE 14

Italy's share of total EU patents: Climate change mitigation (Top 10 countries)



Source: processing based on OECD data

1.2.1.1.

PATENTS FOR CLIMATE CHANGE MITIGATION

According to the classification adopted by the OECD, patents for climate change mitigation cover all patented technologies that aim to reduce greenhouse gas emissions and mitigate the effects of climate change. It therefore includes innovations that promote environmental sustainability through technical solutions applicable to various areas of economic and social activity. This classification aims to organise and make the green innovation landscape more readable, allowing for the analysis of technological evolution in different sectors, the measurement of the contribution of countries or regions to the ecological transition, and the orientation of public policies and incentives towards strategic sectors. This category of mitigation technologies is divided into seven key areas for the ecological transition:

1)Energy generation, transmission and distribution;
2)Transportation;
3)Production or processing of goods, including industrial processes with reduced environmental impact and energy efficiency technologies;
4)Building construction;
5)Wastewater treatment and waste management;
6)ICT (information and communication technologies);
7)Capture, storage, sequestration or disposal of greenhouse gases.

The division into subcategories allows each patent to be associated with a specific field of application. These include the area of energy generation, transmission and distribution, which encompasses technologies for the development and integration of renewable sources, improving energy efficiency and optimising electric grids.

Equally central is the transportation sector, which includes patents aimed at reducing the environmental impact of mobility through electric vehicles, sustainable public transport systems and smart logistics solutions.

In addition, there is the sector relating to the production or processing of goods, which includes all technologies used in industrial processes to reduce emissions, increase the efficiency of production cycles, reduce resource consumption and promote the circular economy.

The building construction sector is also very important, with technologies designed to improve the energy efficiency of buildings, reduce consumption, use sustainable materials and integrate automated management systems.

Another area concerns wastewater treatment and waste management, which includes innovations for recycling, waste reduction and energy recovery.

ICT technologies applied to climate change mitigation are important too, through digital tools that enable the monitoring, optimisation and reduction of energy consumption, for example through smart grids, automated control systems, predictive analytics and environmental management platforms.

18 The sum of the subcategories does not correspond exactly to the higher hierarchical level because there may be patents (IPC codes) that belong to more than one subcategory.

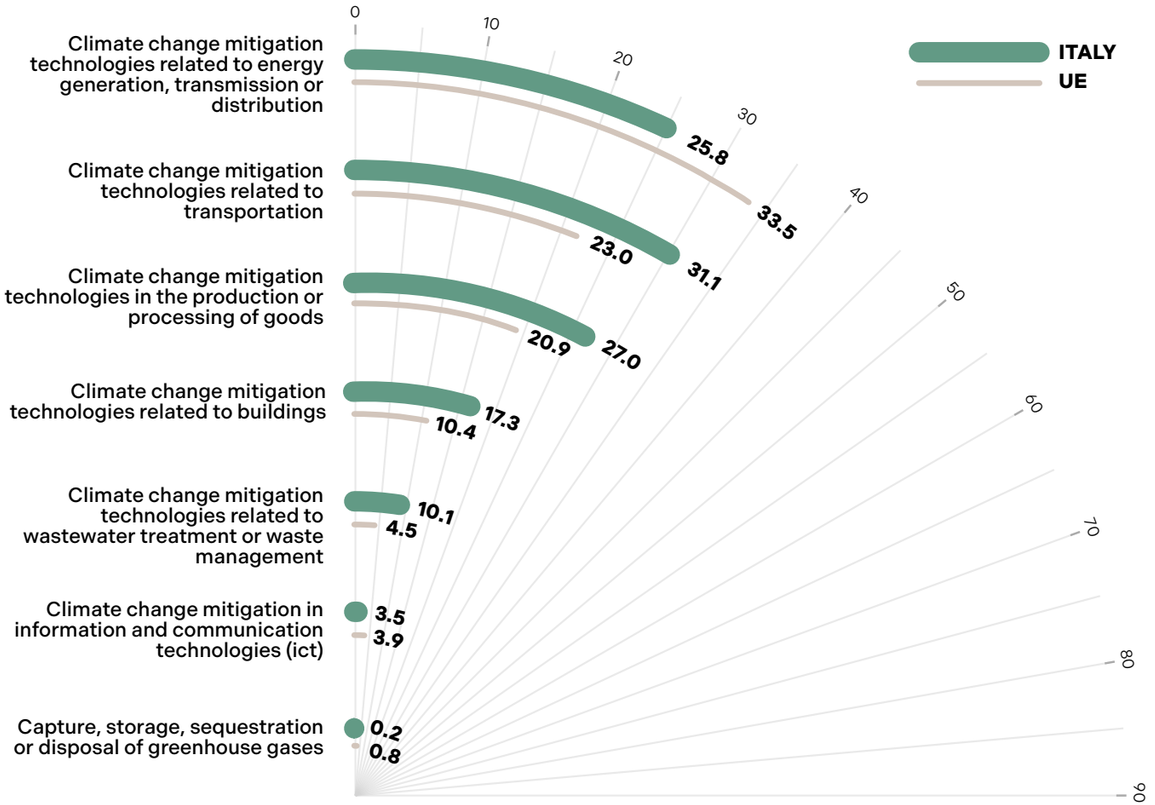
Finally, highly significant are the technologies dedicated to the capture, storage, sequestration or disposal of greenhouse gases, which includes both industrial solutions such as carbon capture and storage (CCS) and more recent approaches such as direct removal of CO_2 from the atmosphere or sequestration using natural techniques.
Together, these seven subcategories represent a sectoral classification model that allows for an applied and strategic interpretation of sustainability-oriented innovation. This approach not only makes it possible to map the technological evolution associated with the ecological transition but also to identify more precisely the sectors on which to focus support actions, industrial policies and public and private investment.
An analysis of the distribution[18] of patents related to climate change mitigation technologies in the European Union highlights a significant concentration in certain key sectors. In particular, technologies related to energy generation, transmission and distribution account for the largest share, with 33.5% of total patents. This figure underlines the importance attached to innovative solutions in the energy sector to address climate challenges. This is followed by technologies applied to transportation, which account for 23.0% of patents, and those used in industrial processes, with a share of 20.9%. These percentages indicate a strong focus on the decarbonisation of transportation and energy efficiency in production processes. Other sectors, such as building construction (10.4%), waste and wastewater management (4.5%) and information and communication technologies (3.9%), have lower shares, while technologies for capturing and storing greenhouse gases account for only 0.8% of the total.

A comparison of these data with the situation in Italy reveals some peculiarities. In Italy, transportation-related technologies account for 31.1% of patents, 8.1 percentage points higher than the European average. Technologies applied to industrial processes also have a higher incidence, with 27.0% of Italian patents compared to 20.9% in the EU. Construction accounts for 17.3% of Italian patents, exceeding the European average by 6.9 percentage points. Waste and wastewater management in Italy accounts for 10.1%, more than double the EU average of 4.5%. These figures indicate that Italy specialises in sectors such as sustainable mobility, energy efficiency in building construction and waste management.

FIGURE 15

Share of patents[19] by subcategory out of total patents for climate change mitigation, Italy, European Union (2022)

19 The sum of the subcategories does not correspond exactly to the higher hierarchical level because there may be patents (IPC codes) that belong to more than one subcategory.



Source: processing based on OECD data

However, Italy has a lower incidence in technologies for energy generation, transmission and distribution, with 25.8% of patents compared to 33.5% in the EU. Information and communication technologies account for 3.5% of Italian patents, slightly below the European average of 3.9%. Finally, Italy accounts for 0.2% of patents for climate change mitigation in greenhouse gas capture and storage technologies, compared to 0.8% for the EU.

Overall, the Italian system shows clear specialisation in certain areas of application of the ecological transition, particularly in sectors more closely related to industrial and urban environments, while remaining weaker in those technologies that are more capital-intensive or linked to the structural transformation of the energy system.

From a dynamic point of view, between 2012 and 2022, the subcategory of environment-related patents that recorded the most marked growth in Europe was that related to ICT technologies for climate change mitigation. Patents granted in this area rose from 69 to 149, an increase of +117.2%. Italy's performance is particularly noteworthy, with an increase of +270.0%, ranking second in Europe, preceded only by Sweden (+308.8%).

Next in terms of growth rate is the category of technologies applied to industrial processes for reducing emissions, which saw an increase of +61.9% (from 491 to 795 patents). In this area, Italy ranks fifth in Europe, growing by +123.3%, while Spain stands out as the most dynamic country with an increase of +254.0%.

In third place in terms of relative growth are technologies for energy generation, transmission and distribution, which grew by +54.7%, from 824 to 1,275 patents. Italy outperformed the European average, with an increase of +65.2%, while Spain confirmed its position as the leading country in terms of dynamism (+249.8%) in this area as well.

The performance of environmental technologies in the building construction sector is also particularly significant, with an increase of +45.1% (from 272 to 394 patents). However, Italy is growing at a slower pace than other European countries (+24.1%), while Denmark stands out with an exceptional increase of +280.0%.

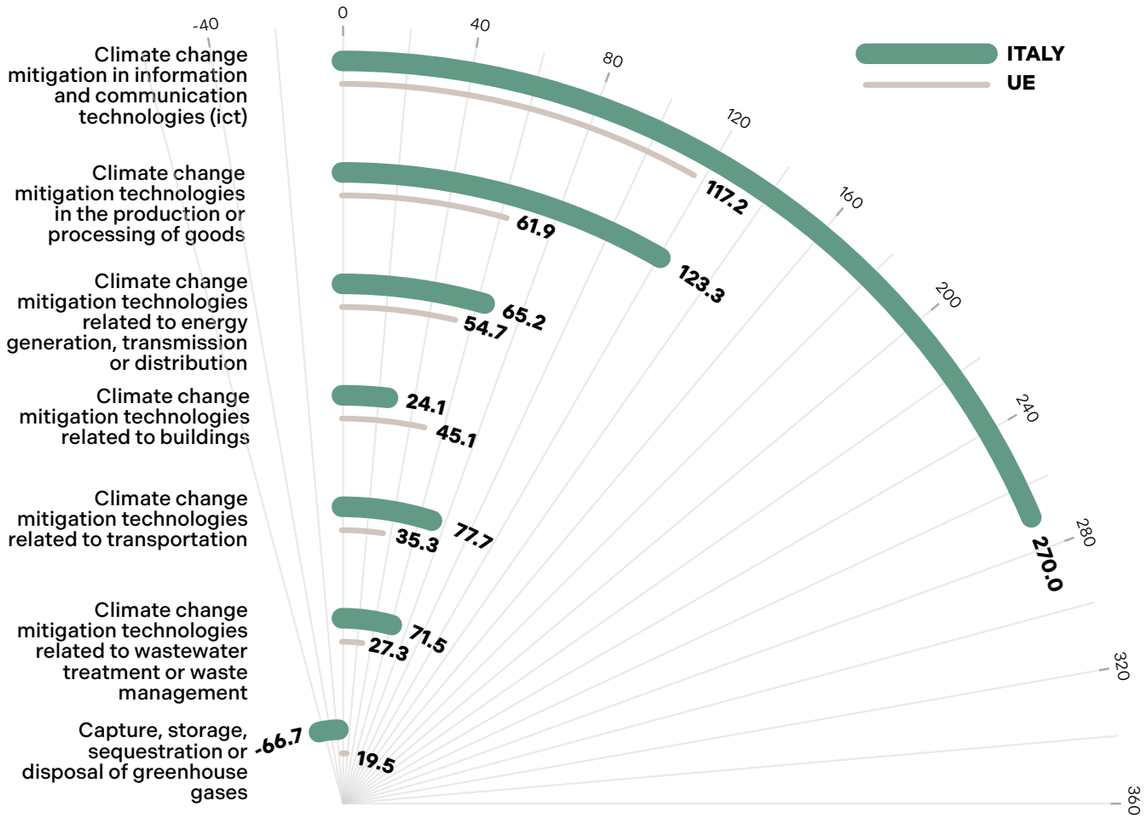
The transportation sector, which is also crucial for the ecological transition, shows a growth in patents of +27.3% (from 649 to 878). Within this context, Italy ranks fifth, showing a +77.7% sustained growth. Once again, Spain stands out as the most dynamic country, with an increase of +217.3%.

The waste management sector, which is central to an effective green transition, also shows significant signs of innovative vitality: patents granted rose from 136 in 2012 to 173 in 2022, representing a growth of +27.3%. Italy stands out for its dynamism in this case, ranking third in Europe with an increase of +71.5%.

Finally, technologies for the capture, storage, sequestration or disposal of greenhouse gases show more modest growth, with an increase of +19.5% (from 24 to 29 patents).

FIGURE 16

Patent growth between 2012 and 2022 according to OECD classification, Italy, European Union (values in %)



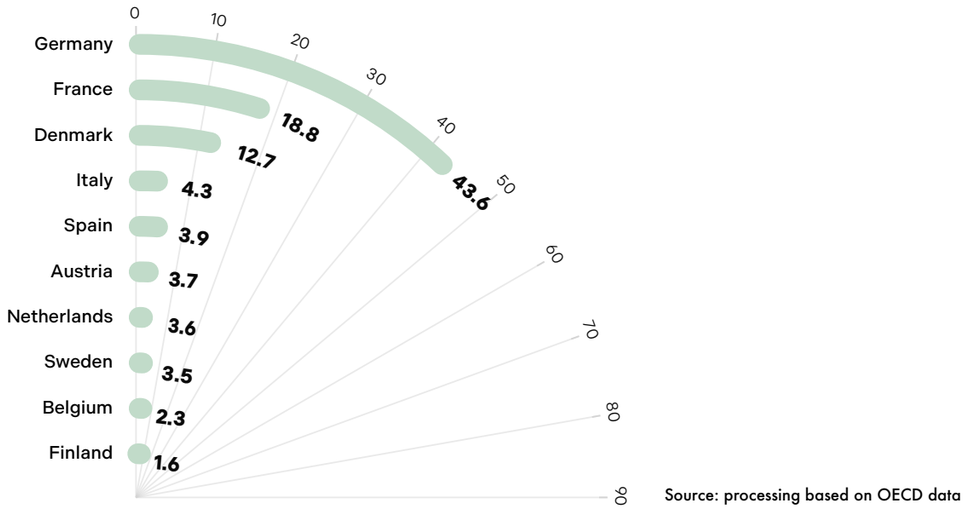
Source: processing based on OECD data

Climate change mitigation technologies related to energy generation, transmission or distribution

Comparing countries, the first subcategory includes patents related to technologies for reducing greenhouse gas emissions in energy production, transmission or distribution, such as renewable energy (solar, wind), smart grids, energy storage and hydrogen. The leading country in terms of number of patents, with a 43.6% share of the EU total, is Germany (556 in absolute terms, compared to 1,275 for the EU as a whole), followed by France (18.8%, 239 in absolute terms) and Denmark (12.7%, 162 in absolute terms). In this respect, Italy ranks fourth with a share of 4.3%. However, if we analyse the incidence on the total number of patents related to climate change mitigation, the country that is highly specialised in innovation in the energy sector, far ahead of the others, is Denmark (with an incidence of 83.5%), followed by Spain (48.3%) and Austria (43.6%), while Italy ranks below the European average (25.8% versus 40.0%).

FIGURE 17

Percentage share of Italy's patents out of the total number of patents in the European Union: Climate change mitigation technologies related to energy generation, transmission or distribution(Top 10 countries)



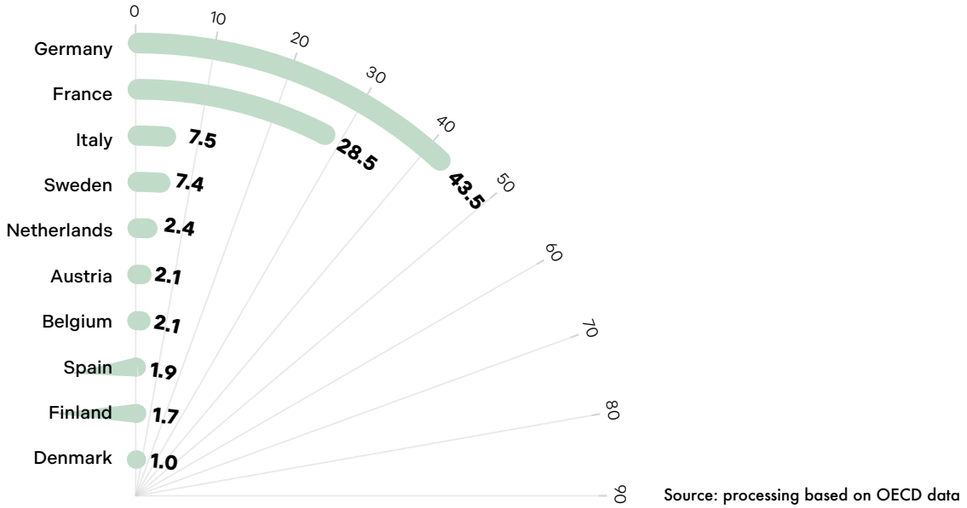
Source: processing based on OECD data

Climate change mitigation technologies related to transportation

The second subcategory concerns technologies for reducing emissions in transportation, such as electric or hybrid vehicles, alternative fuels, aerodynamic design and smart charging. There are 878 patents of this type in the European Union, of which 43.5% are registered in Germany (382 in absolute terms), 28.5% in France (250) and 7.5% in Italy (66). Other countries also feature in the total number of patents for climate change mitigation. The European player most specialised in innovation in this sector is France, with a 40.4% share, followed by Sweden (32.0%) and Italy (31.1%), which ranks above the EU average of 27.6% in this area.

FIGURE 18

Italy's percentage share of total European Union patents: Climate change mitigation technologies related to transportation (Top 10 countries)



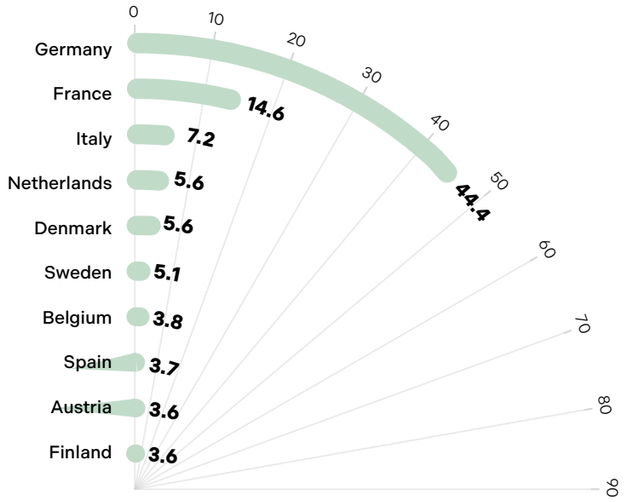
Source: processing based on OECD data

Climate change mitigation technologies in the production or processing of goods

The third subcategory includes technologies aimed at reducing greenhouse gas emissions during the production, transformation or processing of material goods. Within the European Union, there are 795 patents of this type, of which 44.4% are attributable to Germany (353 in absolute terms), 14.6% to France (116) and 7.2% to Italy (58). However, in terms of the total number of patents for climate change mitigation, Finland ranks first with a share of 36.5%, followed by Belgium (35.2%), Spain (28.4%) and Italy, which ranks fourth with a share of 27.0%, exceeding the EU average (25.0%).

FIGURE 19

Percentage share of Italy's patents out of the total number of patents in the European Union: Climate change mitigation technologies in the production or processing of goods (Top 10 countries)



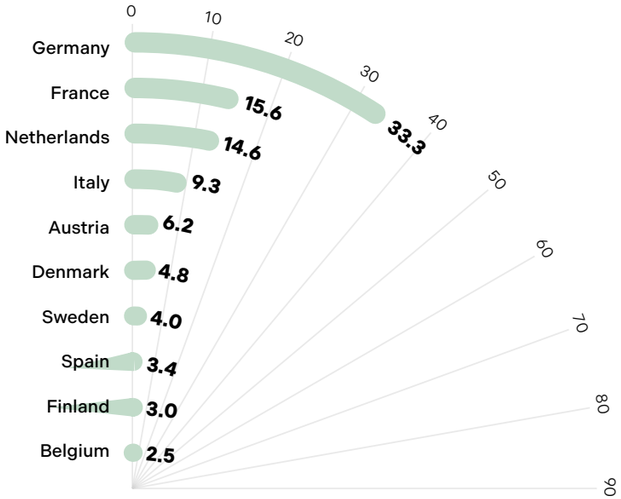
Source: processing based on OECD data

Climate change mitigation technologies related to buildings

The fourth subcategory includes all technologies aimed at integrating renewable energy sources into buildings or improving their energy efficiency, for example through thermal insulation, home automation or heat pumps. In the European Union, 394 patents of this type were granted in 2022, accounting for 12% of all patents related to climate change mitigation. In particular, the countries that issued the most patents were Germany (33.3%, 131 in absolute terms), France (15.6%, 62) and the Netherlands (14.6%, 57), which together hold 63% of the European Union's patents. In terms of incidence, however, the leading country in terms of the share of this subcategory of patents out of the total number of mitigation patents is the Netherlands (34.0%), followed by Austria (22.7%) and Italy (17.3%), compared to a EU average of 12.4%.

FIGURE 20

Italy's share of patents as a percentage of total European Union patents: Climate change mitigation technologies related to buildings (Top 10 countries)



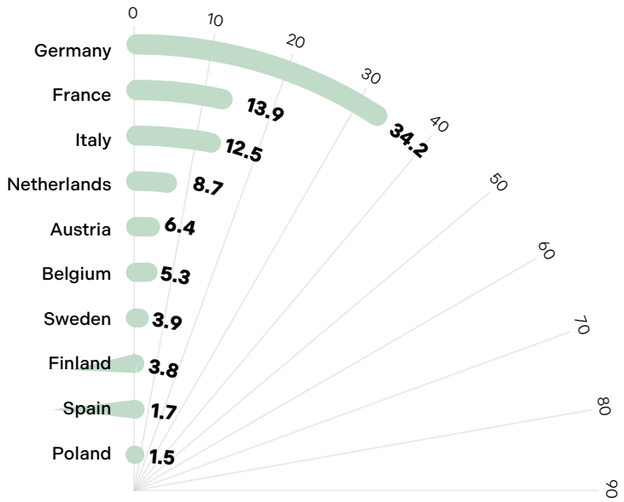
Source: processing based on OECD data

Climate change mitigation technologies related to wastewater treatment or waste management

The fifth subcategory of patents comprises a set of technologies for the sustainable management of wastewater and waste, aimed at reducing GHG emissions. In the European Union there are a total of 173 patents in this category, of which 34.2% are concentrated in Germany (59 in absolute terms), France (13.9%, 24 in absolute terms) and Italy (12.5%, 22 in absolute terms). However, Belgium is the country with the highest incidence of these patents, at 10.8%, although it is not far behind Austria and Italy (with shares of 10.3% and 10.1% respectively), compared to an EU average of 5.4%.

FIGURE 21

Italy's share of total EU patents: Climate change mitigation technologies related to wastewater treatment or waste management (Top 10 countries)



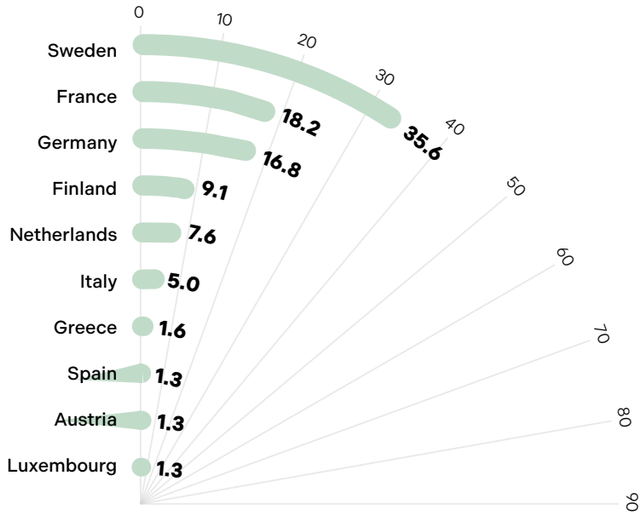
Source: processing based on OECD data

Climate change mitigation in information and communication technologies (ICT)

The sixth subcategory of patents concerns patented technologies that contribute to reducing greenhouse gas (GHG) emissions through energy efficiency in the IT and telecommunications sectors. There are 149 patents in this category in the European Union, of which 35.6% are concentrated in Sweden (53 in absolute terms), 18.2% in France (27) and 16.8% in Germany. In terms of percentage of the total number of patents related to mitigation, Sweden stands out with a share of 26.2%, followed by Finland (17.1%) and the Netherlands (6.7%). Italy ranks below the EU average in this regard, with a share of 3.5% (4.7% average value).

FIGURE 22

Italy's share of total European Union patents: Climate change mitigation in information and communication technologies (ICT) (Top 10 countries)



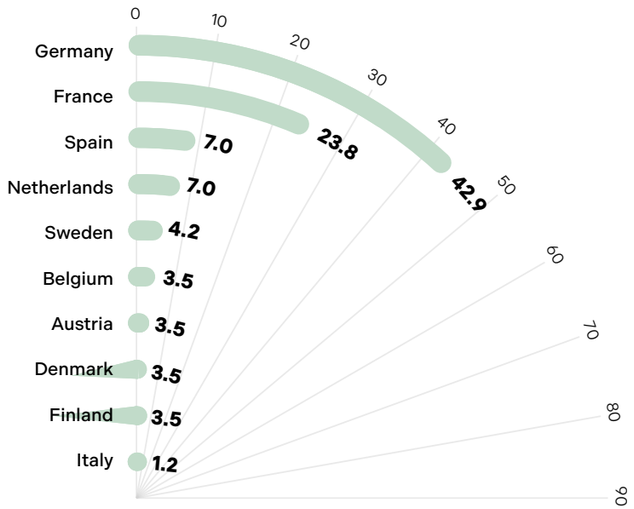
Source: processing based on OECD data

Capture, storage, sequestration or disposal of greenhouse gases

Finally, the last subcategory concerns patents relating to technologies that capture and store greenhouse gases (CO_2, CH_2, N_2O, etc.). This category, with a total of 29 patents in the European Union, accounting for less than 1% of the total, is residual. The countries with the highest number of registered patents are Germany, with 42.9% of the total, France (23.8%) and Spain (7.0%), while Italy ranks last in the top 10 with 1.2%.

FIGURE 23

Italy's share of total European Union patents: Capture, storage, sequestration or disposal of greenhouse gases (Top 10 countries)



Source: processing based on OECD data

chap. 2

THE TREND IN ITALIAN GREEN PATENT APPLICATIONS[20]

20 For the analyses carried out in this section, we used the *Unioncamere-Dintec Patent, Trademark and Design Observatory* database. This database allowed us to extend the analysis of Italian European patent applications published both in terms of time (analysing applications published by the EPO until 2024) and in terms of analysis variables (integrating applications with information on companies taken from the Italian Business Register and Istat).

The first chapter analyses **granted patents**, i.e., those patents that have already passed the patentability examination at the competent office. At this stage, the invention has been assessed as new, original and industrially applicable, and for this reason has been officially approved. The owner thus obtains exclusive rights to the invention for a specified period (usually twenty years), and the patent becomes fully legally effective: it can therefore also be enforced in court in the event of infringement. We chose to start with this data because it represents the most consolidated and up-to-date information available in the OECD database, which is useful for ensuring a consistent comparison at European level.

In this second chapter, however, we will analyse **published patent applications**, i.e., those patent applications which, although not yet approved, have been made public by the patent office after an initial period of confidentiality (generally 18 months from the filing date). The purpose of publication is to inform the public of the existence of the application, but it does not yet confer any exclusive rights: the invention is still under evaluation and may be partially modified or even rejected.

In this chapter, we will focus on an analysis[21] of Italian patenting trends at the European Patent Office (EPO) in the green sector, providing a detailed focus on the technologies and entities that patent green technologies. Although it has the limitations mentioned in the previous chapter, this type of analysis, which emphasises patenting by Italian entities in Europe, has the advantage of highlighting the technologies in which entities using industrial protection tools are investing the most. Within the companies, therefore, this type of activity must be carefully planned and programmed within a development frame that is not solely technological but above all economic and strategic (for example, with a view to expansion into new markets or towards an also communicative positioning). We will also discuss patents that refer to technologies capable of reducing the environmental impact of production processes and products, improving energy efficiency, exploiting renewable energy sources, promoting the circular economy and sustainable resource management, and contributing to climate change mitigation.[22]

In this context, the value of sustainability in terms of patents is clear, especially from a forward-looking perspective. Although these patents still represent a limited share of the total in recent years (2016–2024), they have grown significantly, by +55.6%. The trend in this case is much more volatile than the general curve. Let us look at the trend in more detail:

- After an initial surge in 2017 (+23.2%), the trend stabilised, then recorded more marked growth in 2019 (+39.5%) and a setback in

21 The analysis of Italian companies' patent applications at the EPO and WIPO was carried out by DINTEC, a consortium for technological innovation.

22 In the database examined, we classified patent applications as 'green' with reference to the IPC Green Inventory taxonomy also used by the World Intellectual Property Organisation (WIPO), the specialised agency of the United Nations founded in 1967 to encourage creative activity and protect intellectual property worldwide.

2020[23], probably linked to the uncertainties and impacts of the pandemic crisis.

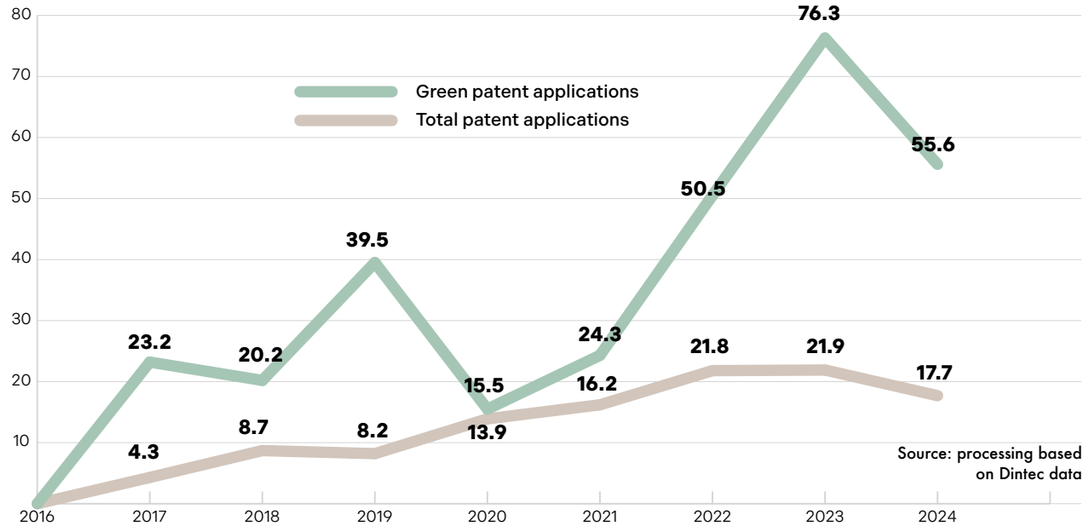
- However, there is a significant acceleration from 2021 onwards, peaking in 2023 (+76.3%), a sign of renewed attention to environmental technologies. The slight decline in 2024 does not compromise the overall picture, which remains clearly on the rise compared to the starting point.

This trend confirms that, although green patents still represent a minority share of total Italian applications, their prevalence is increasing, especially in recent years. This is an encouraging sign: businesses and innovation players are gradually integrating sustainability into their research and development processes, thus responding to the challenges posed by the double transition. The growth in green patents is not only a statistical indicator but also a reflection of a cultural and strategic change taking place in the Italian production system.

23 Please note that the publication date of the patent application is at least 12 months later than the actual filing date.

FIGURE 24

Trend in published Italian European patent applications (2016–2024): green applications compared to total Italian patent applications (percentage values)



Source: processing based on Dintec data

2.1.

THE MAIN GREEN TECHNOLOGIES PATENTED IN ITALY

An analysis of the IPC subclasses of patent applications published between 2016 and 2024 allows us to identify the technological areas on which research and development investments in the green transition are concentrated. This survey not only provides a snapshot of the most widespread solutions but also allows us to recognise the emerging trajectories that are redefining the profile of environmental innovation in Italy. An examination of the top ten green technologies by number of patents reveals, first and foremost, the strong presence of solutions related to the digitisation of production processes and the efficient management and environmental resources. Subclass G06Q – which includes digital technologies and computer systems designed to support administrative, management and financial activities – is clearly the most significant, with 296 patent applications published during the period, accounting for 12.0% of the total. These are a set of innovations that contribute to sustainability by improving the efficiency of internal processes and reducing consumption, waste and emissions.

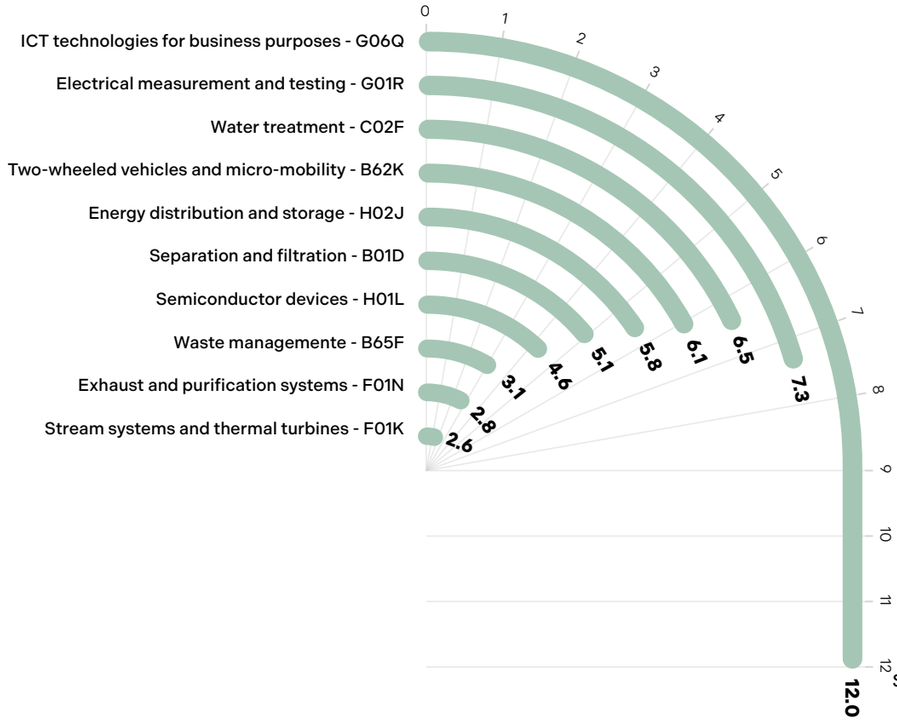
This is followed at some distance by class G01R, which includes 181 patents (7.3%) relating to technologies for measuring and testing electrical and magnetic variables. This includes instruments and systems for monitoring voltage, current and material properties, as well as devices for testing electrical equipment, up to applications based on spin effects such as NMR and EPR. These are crucial solutions for ensuring high energy performance and accurate testing of electrical infrastructure.

The third most important area is class C02F, related to technologies for the treatment of wastewater, sewage and sludge. With 161 patents (6.5%), this sector confirms

the centrality of sustainable water management policies that are increasingly strategic in a context of growing attention to environmental protection.
Among the most widespread technologies is class B62K, relating to bicycles and micro-mobility vehicles, with a total of 151 patents (6.1%) concerning frames, steering systems, suspensions and various devices that make these vehicles increasingly efficient and competitive. In addition to soft mobility, the energy sector is also strengthening, represented by class H02J, which, with 144 patents (5.8%), includes solutions for alternating or direct current distribution networks, battery management and charging systems, multi-source power supply and even technologies for wireless energy transmission.
Physical separation process, which includes class B01D, is an another expanding sector. With 126 patents (5.1%), this includes technologies such as evaporation, distillation, crystallisation, filtration and gas purification, as well as absorption and adsorption processes, which are used in a wide range of production and environmental activi-

FIGURE 25

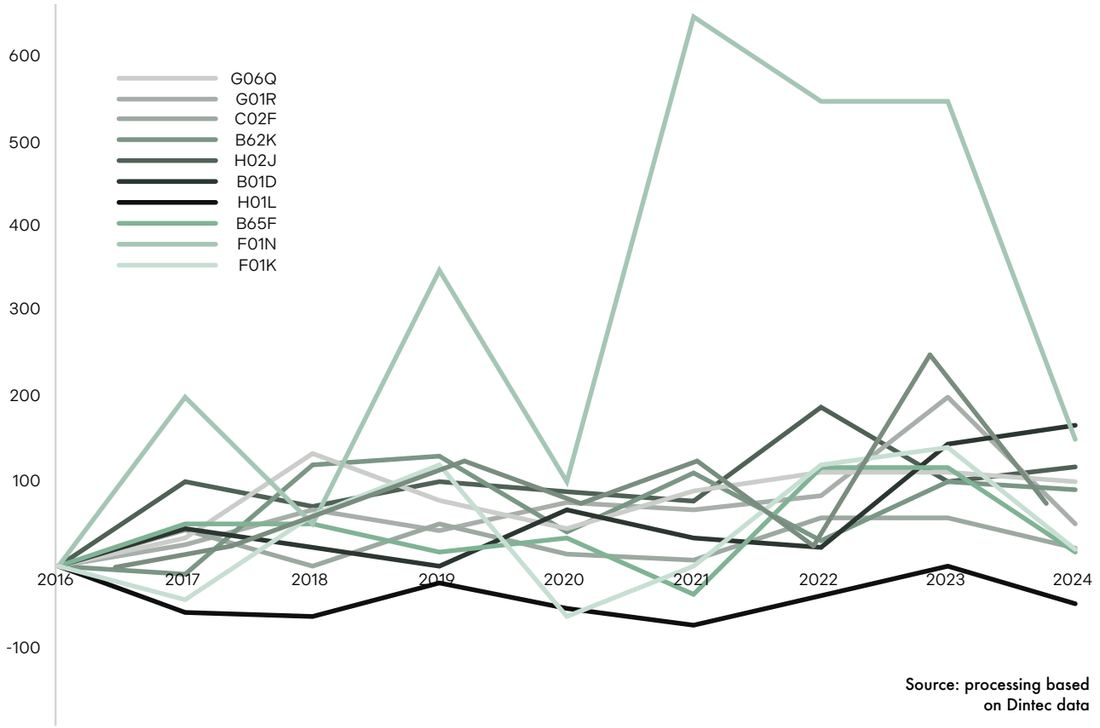
Percentage distribution of the main green IPC subclasses of patent applications published in Italy between 2016 and 2024



Source: processing based on Dintec data

FIGURE 26

Trend of the top 10 IPC subclasses in the green sector, 2016-2024 (percentage values)



Source: processing based on Dintec data

ties. Advanced electronics also continue to play an important role: class H01L, with 113 patents (4.6%), includes semiconductor devices that are crucial for energy conversion and control in photovoltaic systems.
Three other technological areas complete the ranking. The collection and removal of domestic or similar waste (class B65F) totals 76 patents (3.1%), while exhaust and purification systems for internal combustion engines (class F01N) reach 70 (2.8%), highlighting a continuous commitment to reducing emissions. Finally, class F01K, dedicated to steam plants and special thermodynamic cycles, accounts for 63 patents (2.6%). Although this is a traditionally consolidated sector, it continues to innovate by introducing new fluids and more efficient configurations, thus maintaining a prominent role in innovative energy solutions.
Finally, looking at the temporal dynamics of patent applications published between 2016 and 2024, one sees that some subclasses show particularly significant increases. Separation and filtration processes (B01D) lead the growth trend, with an increase of 166.7% between 2016 and 2024, followed by exhaust and purification systems (F01N), which grew by 150.0%. There has also been a very strong increase in patents related to ICT technologies for business purposes (G06Q), which are up 117.6%, while class H02J – dedicated to energy distribution and storage – has doubled in published applications (+100.0%). Micro-mobility (B62K) also showed significant growth, up 90.0%, a sign of the progressive establishment of light, low-environmental-impact transportation solutions.
Overall, the Italian patent landscape highlights a rapidly changing innovative ecosystem in which digitalisation, energy efficiency and circular resource management are the main pillars of the new green technological trajectory.

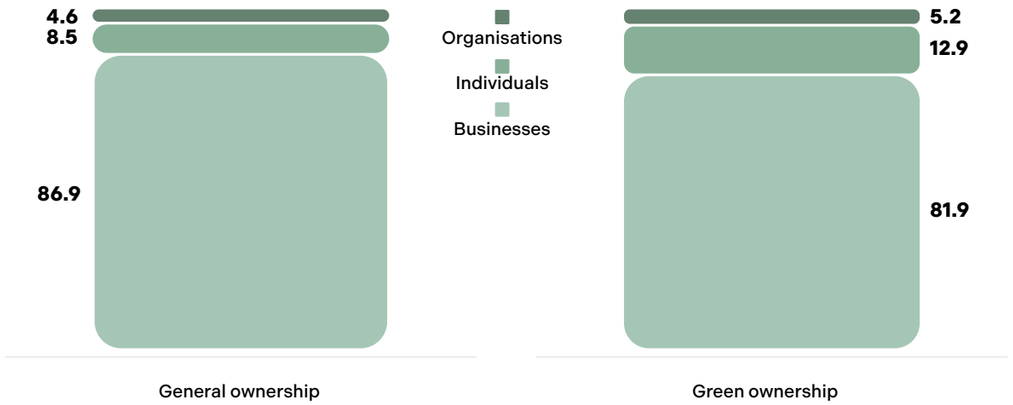
2.2. INNOVATION PLAYERS AND PATENT INTENSITY IN ITALY

To complete the picture, it is useful to analyse who the owners of published patent applications are, i.e., which entities choose to legally protect their inventions.
Of all Italian European patent applications published between 2016 and 2024, companies hold 86.9% of the titles, followed by individuals (8.5%) and public or private organisations (4.6%), with no foreign entities involved. A very similar dynamic can be observed in the case of green patent applications, where companies hold 81.9% of published applications. In this area there is a higher incidence of individuals (12.9%), while organisations account for 5.2%, in line with the overall average. This slight increase in individual participation in the green sector may reflect greater environmental awareness on the part of individual inventors or small research groups, but it does not alter the overall picture: companies remain the main players in green patenting.
Having highlighted that companies are the main holders of patent applications in Italy – with a clear predominance in both total applications (86.9%) and green applications (81.9%) – it is interesting to examine the trend over time in patent applications published by companies, distinguishing between those of companies that patent in general and those that develop green technologies. The comparison reveals a distinctly different dynamic. Patent applications by Italian companies as a whole show a gradual and steady growth trend: from 2016 to 2024, there was an increase of 18.7% compared to the base year. This trajectory confirms a stable presence in the patent system, consistent with the central role that com-

panies play in national technological innovation. On the contrary, companies that have published green patent applications show a much livelier and more fluctuating trend but with a decidedly more marked growth: +74.3% in 2024 compared to 2016, with an extraordinary peak reached in 2023 (+105.3%). This gap suggests that, although still a minority, green innovation represents an area of growing investment for Italian companies, probably also in response to regulatory stimuli and European policies in the environmental and energy fields.

FIGURE 27

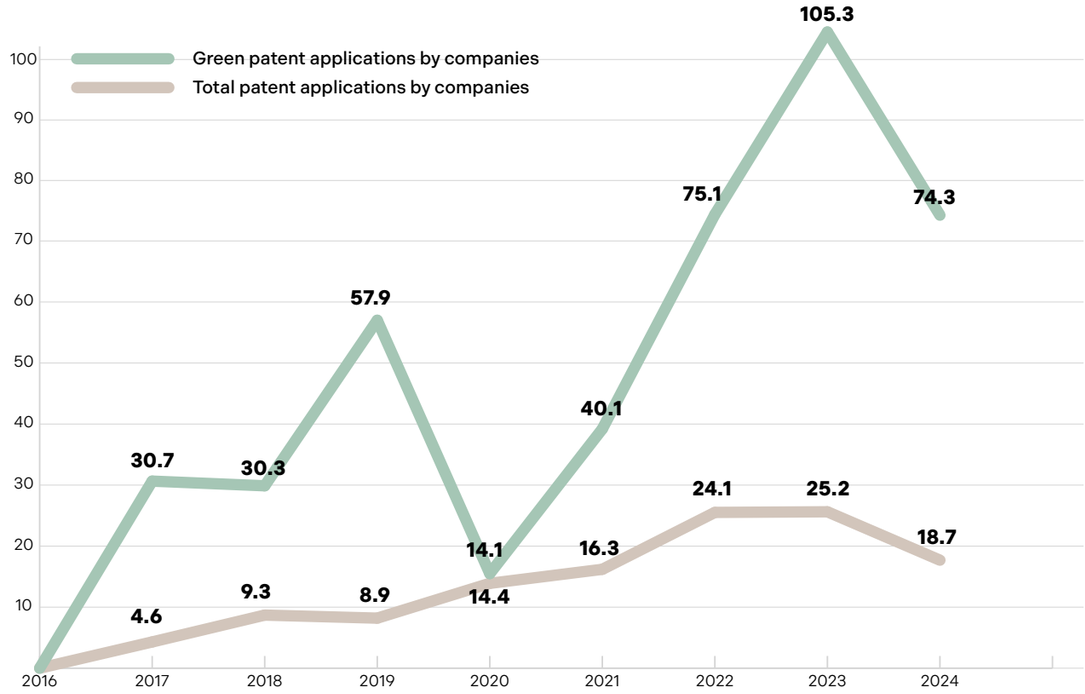
Percentage distribution by type of owner for published Italian European patent applications



Source: processing based on Dintec data

FIGURE 28

Trend in Italian European patent applications published by companies (2016-2024): green applications compared to total Italian patent applications (percentage values)



Source: processing based on Dintec data

chap. 3

SECTORAL AND TERRITORIAL GEOGRAPHY OF ENVIRONMENTAL ECO-INNOVATION[24]

24 The variables relating to businesses refer to 2022.

3.1. TERRITORIAL AND SECTORAL DISTRIBUTION OF COMPANIES FILING GREEN PATENT APPLICATIONS

Focusing on businesses allows for a more accurate delineation of the geographical and sectoral geography of innovation, offering a detailed reading of the country's patenting capacity. Analysing patent applications reveals a marked geographical concentration, which is more intense in some Italian regions of the North than in the rest of the country. The regions with the highest patent intensity are Lombardy, Veneto, Emilia-Romagna and Piedmont, areas characterised by a strong manufacturing presence, a dynamic entrepreneurial fabric and a consolidated tradition in the technological and industrial fields. These areas not only generate the highest number of applications in absolute terms but also represent the country's main innovation hubs. Conversely, the southern regions and some areas of central Italy show lower patent intensity, highlighting a territorial divide that reflects structural inequalities in terms of the number of businesses, investment in R&D, the presence of university hubs and innovative networks, and access to intellectual property protection tools.

This territorial distribution becomes more pronounced in the light of the analysis of green patenting: the most active regions in general terms are also those that lead innovation, contributing most to the development of technologies geared towards the green transition.

An analysis of the sectoral distribution of Italian European patent applications in the green field shows that patented green technologies differ according to the econo-

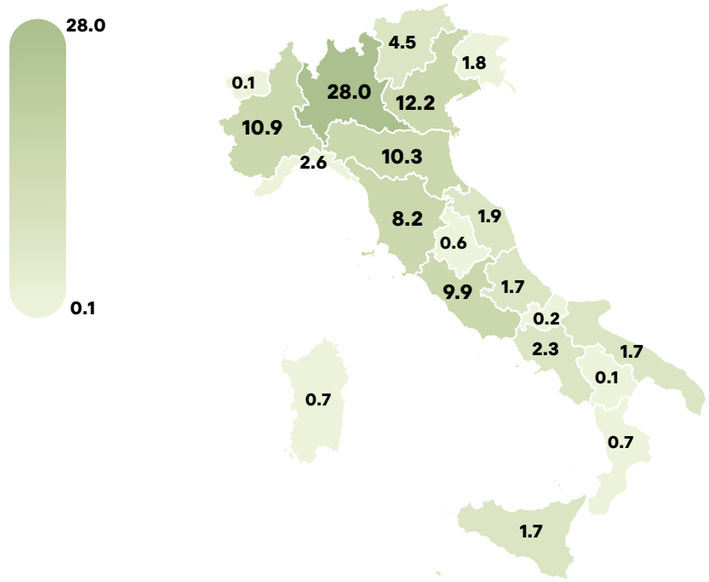
mic sectors concerned.[25] This perspective not only allows us to identify the areas of technology that are most innovative, but also to understand which sectors are most dynamic and involved in the country's green transition process. Manufacturing remains the main driver of green innovation, with a strong concentration of patents in pollution control (19.1%), vehicles (12.8%) and electricity consumption measurement (10.6%). These figures reflect the industry's commitment to reducing the environmental impact of production processes and improving energy efficiency, in line with the challenges posed by decarbonisation and international competitiveness. Within the manufacturing sector, looking at the details[26], the sectors with the highest number of published patent applications are: manufacture of machinery and equipment n.e.c. (269 patent applications between 2016 and 2024), manufacture of other transportation equipment (161 patent applications), manufacture of computers and electronic equipment (147 patent applications), manufacture of motor vehicles, trailers and semi-trailers (126 patent applications) and manufacture of electrical equipment (93 patent applications).

25 The study refers to the ATECO 2007 classification.

26 of the 2-digit Ateco sectors

FIGURE 29

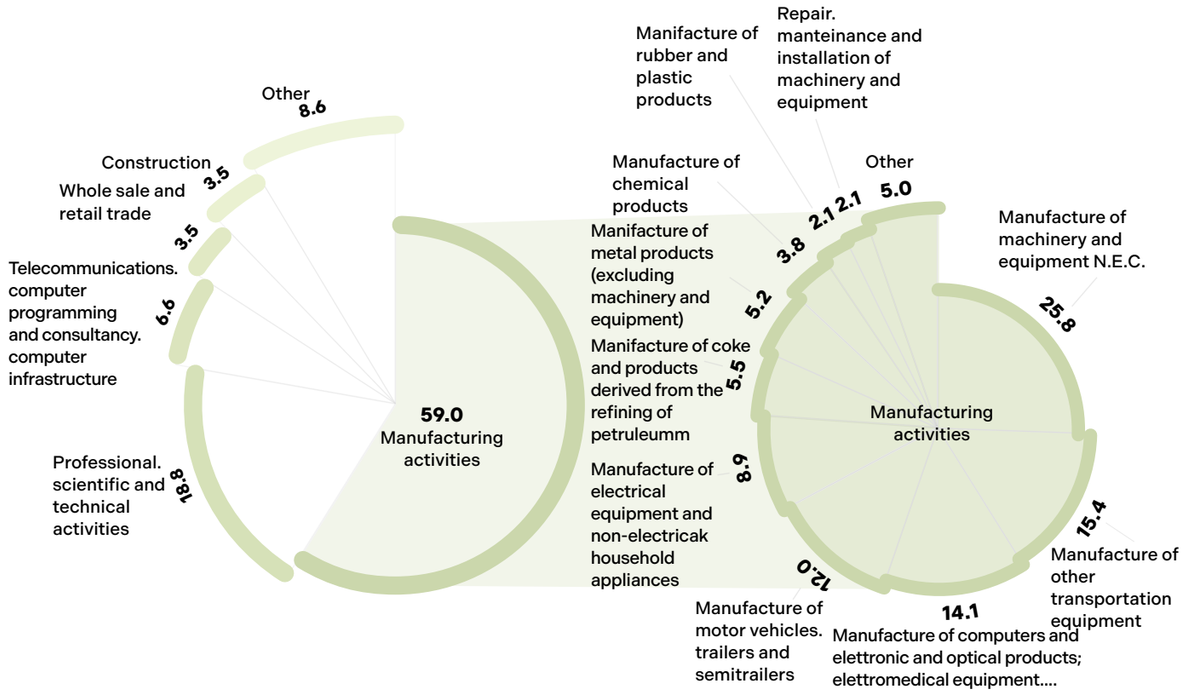
Percentage distribution of green patent applications by region



Source: processing based on Dintec data

FIGURE 30

Percentage distribution of Italian European patent applications in macro-sectors, and details of manufacturing



Source: processing based on Dintec data

In dynamic terms, however, the sectors showing the greatest growth are manufacture of chemical products (+166.7% between 2016 and 2024), manufacture of rubber and plastic products (+148.0%), manufacture of motor vehicles, trailers and semi-trailers (+126.8%), manufacture of other transportation equipment (+112.5%) and manufacture of computers and electronic equipment (100.0%).

The professional, scientific and technical sector also shows a significant propensity for environmental innovation, with a focus on pollution control (16.2%) and solutions related to sustainable mobility and flexible labour (12.7%). This suggests a growing role for applied research and technical consulting in the development of cross-sector green solutions. Within this category, we find the second sector in terms of the number of green patent applications, scientific research and development (198 applications between 2016 and 2024), but also business management and management consulting (52 patents) and architectural and engineering firms (52 patents). Furthermore, between 2016 and 2024, there was strong growth in green patenting in research and development (+315.4%).

Particularly interesting is the data relating to the telecommunications and IT services sector, where over 74% of green patents concern technologies for smart mobility and remote working. This highlights how digitalisation can make a decisive contribution to sustainability by reducing travel and optimising the use of resources. In this category, patenting is concentrated in the sector (Ateco 2 digits) of software production, IT consulting and related activities (87 patents published between 2016 and 2024), the sector with the highest growth in green patents (+400.0%).

In wholesale and retail trade, green innovation is concentrated on several fronts ranging from sustainable mobility (24%) to electricity consumption measurement (15.3%), solar energy (13.1%) and thermal insulation of buildings (10.9%). This shows that even sectors traditionally less involved in R&D can play an active role in the ecological transition, especially through the adoption and dissemination of sustainable technologies. In this section, patent applications are concentrated almost exclusively in the wholesale trade sector (excluding motor vehicles and motorcycles) (54 green patents), which has also seen strong growth in recent years (+116.7% between 2016 and 2024).

Finally, in the construction sector, pollution control is the main area of innovation (37.5%), followed by technologies for railway vehicles and geothermal energy (both at 13.2%). This is a strategic sector for urban sustainability, where innovation can have a profound impact on the environmental quality and energy efficiency of buildings and infrastructure. Finally, in construction, 'green' patenting is divided between the specialised construction works sector (30 green patents) and building construction (22 patent applications), with the former seeing a sharp increase in applications in recent years (+200.0%).

3.2. THE PERFORMANCE OF COMPANIES THAT PATENT GREEN TECHNOLOGIES

In recent years, technological innovation geared towards sustainability has taken on an increasingly central role in the growth strategies of Italian companies. In this context, green patents are not only an indicator of innovative capacity but also a sign of competitiveness. Analysing the characteristics of companies that publish green patents therefore allows us to understand the peculiarities of a dynamic and strategic segment of the national production fabric, highlighting differences and strengths compared to companies that patent other technologies.

Looking at the size, companies that have published green patents are larger – in terms of employees – than those that have published other types of patents. Starting with small businesses (0-49 employees), 55.1% of companies with green patent applications are small compared to 64.7% of companies that have patented other technologies. In the medium-sized category (50-249 employees), companies with green patent applications account for a smaller share: 22.9% compared to 26.8%. In the large category (250 or more employees), however, the difference is more pronounced, with a significantly higher share of companies with green patents: 22.0% vs 8.5%.

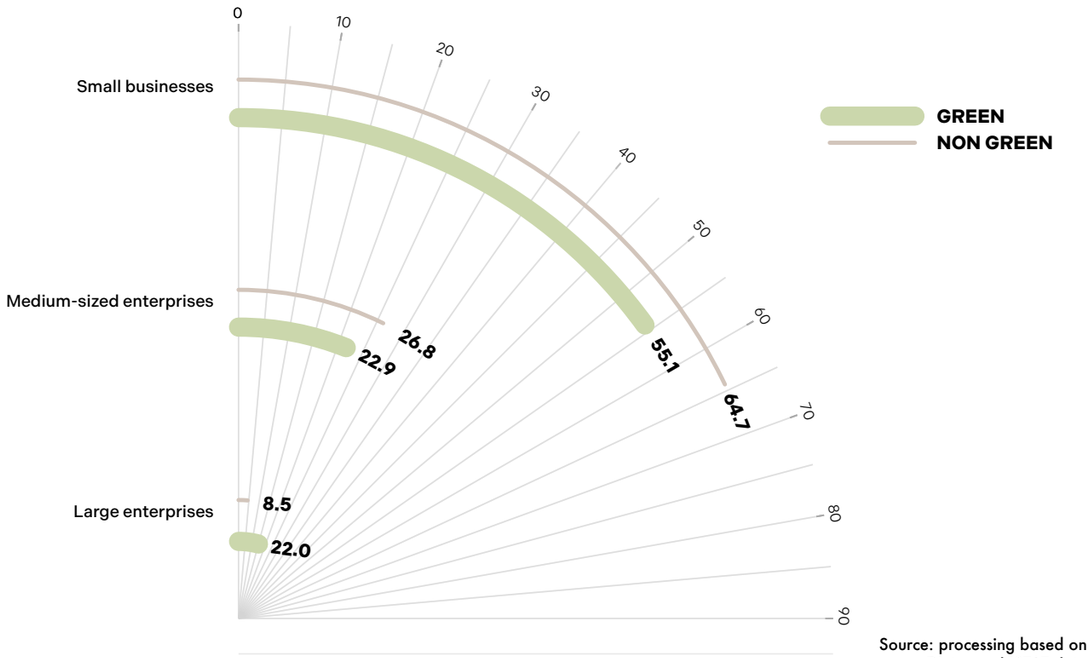
From an economic point of view, in 2022 the group of companies holding patent applications in environmental technologies generated a turnover of approximately €270 billion, with higher turnover intensity and greater productivity.

This is a group of highly productive companies, with an average turnover of €382 million per company. Companies that have filed patents in non-green technologies, on the other hand, have a significantly lower turnover intensity (€41 million per company), partly due to the smaller share of large companies.

In terms of productivity, companies with environmental patent applications have very high values, with an added value per employee of around €144,000 (compared to €92,000 for others).
Companies that patent environmental technologies, more than half of which are exporters (57.8%), are characterised by significant diversification in both products and markets: on average, each one exports 61 different products to 32 countries. The main destinations include the United States, which accounts for 16.8% of Italian 'green exports', followed by Germany (10.1%) and China (3.0%). Companies that patent other technologies are less diversified: they export on average to 28 countries and 28 different products. The three main export markets remain unchanged, with the United States in first place (13.0%), Germany in second (12.0%) and China in third (3.6%).
Looking more closely at human capital, companies that have filed green patents have a more highly qualified workforce on average, with 29.7% of employees holding a degree[27] and 16.8% of employees holding a degree in STEMplus disciplines (i.e., te-

FIGURE 31

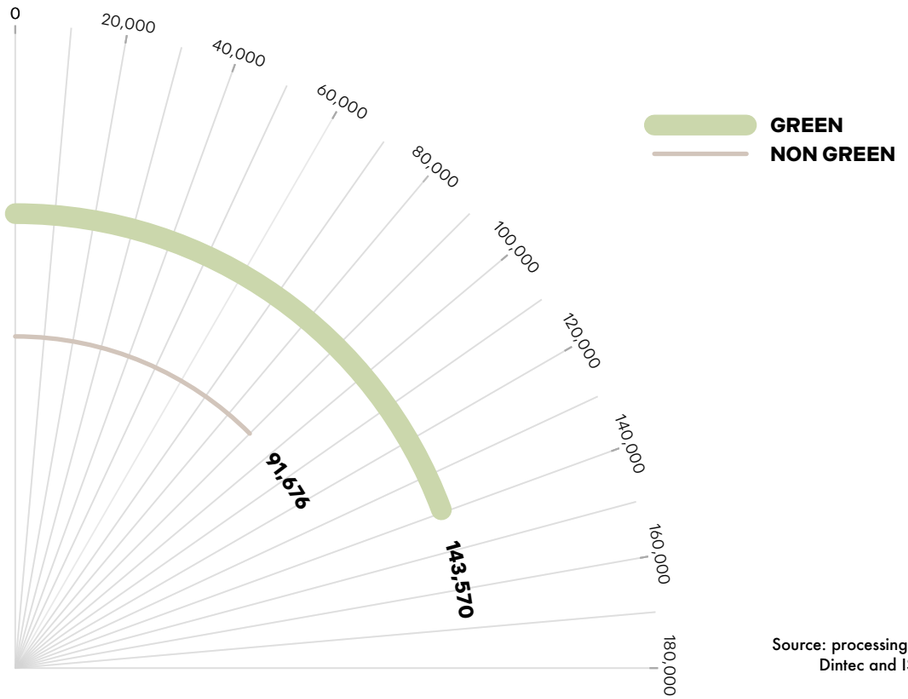
Size of companies filing green patent applications vs companies filing non-green patent applications



Source: processing based on Dintec and ISTAT data

FIGURE 32

Labour productivity in companies filing green patent applications vs companies with non-green patent applications (thousands of euros)



Source: processing based on Dintec and ISTAT data

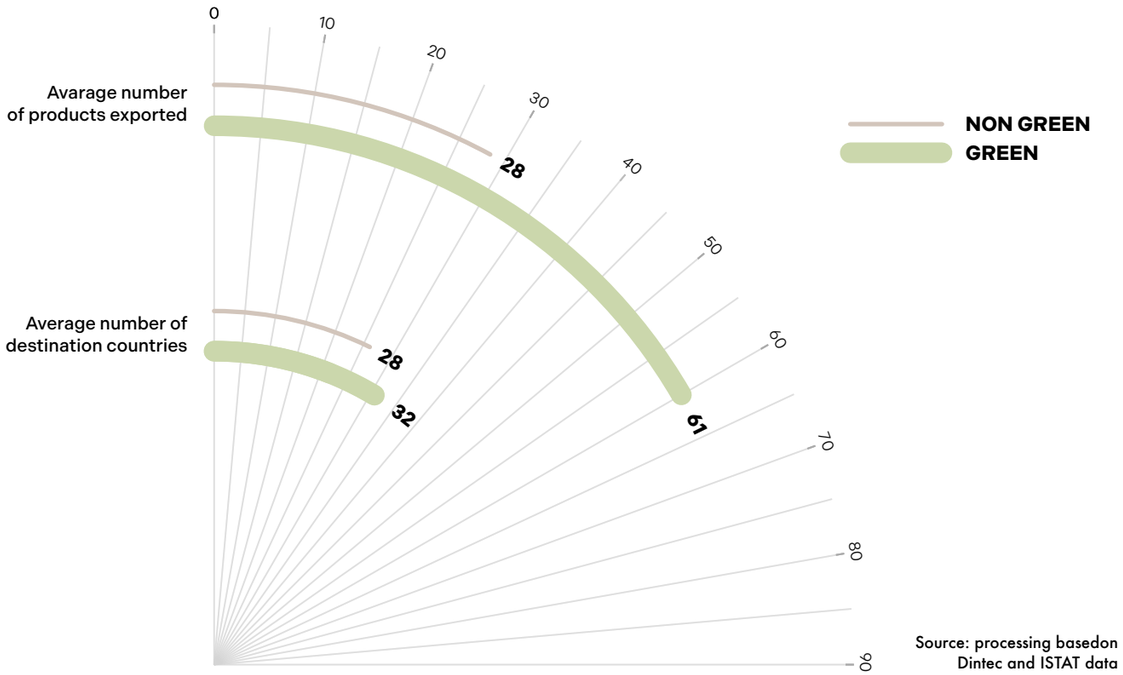
27 Graduates are defined as persons holding a first or second level degree or a doctorate.

chnical-scientific, economic and statistical fields), thereby highlighting a focus on highly qualified skills. The figures are lower for companies that patent other technologies: 26.4% of employees have a degree and 13.8% have a STEMplus degree.

Finally, one last important dimension emerges: as many as 41.9% of companies filing patent applications in the environmental field have foreign participation in their corporate structure, while in companies that patent other technologies the share drops to 31.7%. This factor not only reflects the international appeal of Italian companies operating in the sector but also suggests the existence of innovative transnational supply chains, in which Italy plays a central role in the production of sustainable technologies.

FIGURE 33

Product and market diversification of companies filing green patent applications vs companies filing non-green patent applications

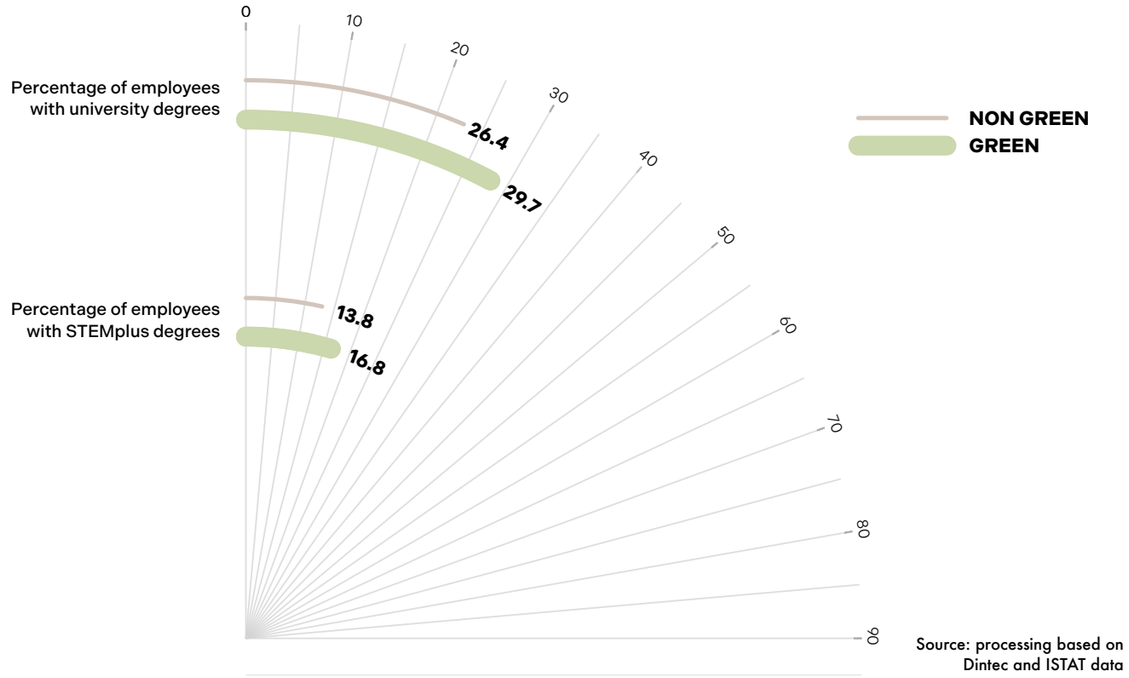


Source: processing basedon Dintec and ISTAT data

Econometric analysis was used to better isolate the specific impact of this factor in order to accurately measure the 'green' effect on company performance. This approach was necessary because, as highlighted above, companies that patent green technologies have structural characteristics that differ from those of companies that patent technologies not related to sustainability – These characteristics, such as the size of the company, can influence the company's performance.. This makes it essential to have a method capable of distinguishing the 'green' effect from that linked to the company structure. The econometric analysis, which compared companies that patent green technologies with those that patent non-green technologies, shows that green innovation is associated

FIGURE 34

Human capital of companies filing green patent applications vs companies filing non-green patent applications



Source: processing based on Dintec and ISTAT data

with better economic results in the medium term. Between 2017 and 2022, companies with patent applications in green technologies recorded, with the same structural, territorial and sectoral characteristics, an average growth in added value approximately 10.9% higher than those innovating in other areas. Labour productivity growth was also higher on average for green companies, with an estimated advantage of around 5.4%, although this is smaller and less statistically significant.

Overall, the results suggest that commitment to sustainability-oriented innovation is not only a choice of environmental responsibility but also a competitive factor that can promote growth and improve production efficiency.

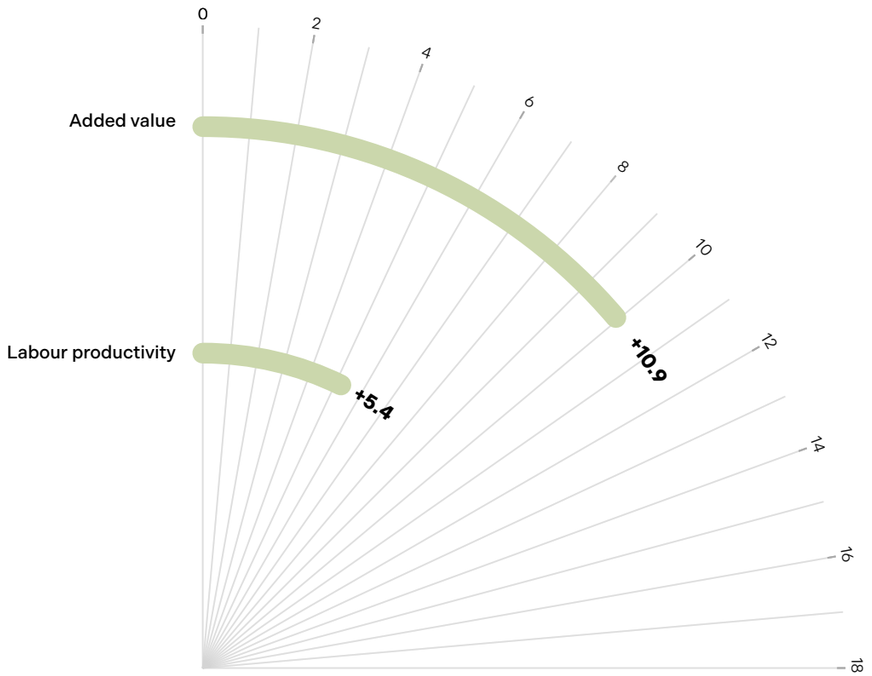
Among the control variables, the positive role of the proportion of employees with technical-scientific or economic-statistical training (STEMplus) leaps to the eye, as it has a significant impact on the increase in added value. Regional differences are also important: some areas (the South) show more dynamic trends than the average (for more details, see Appendix A2).

To complete the picture of green innovation in Italy it is also useful to look at the main industrial players driving this process. Among the companies that dominate for the number of European patent applications in the environmental field published between 2016 and 2024, prominent names in the national industrial landscape stand out. Piaggio & C. S.p.A., for example, is a benchmark in the sustainable mobility sector, while ENI S.p.A. demonstrates the commitment of large energy companies to converting to cleaner technologies. STMicroelectronics S.r.l. and Technoprobe S.p.A., on the other hand, focus on electronics and microtechnology, key sectors for energy efficiency and green digitalisation. Saipem S.p.A., active in engineering and energy infrastructure, confirms that heavy industry is also investing in sustainable solutions.

Finally, it is interesting to note that the landscape of Italian companies most active in green patenting differs slightly from the general picture. There are slight differences among the companies that stand out for the number of European patent applications in the environmental field. In this context, if we look at the overall picture of patenting, other players also emerge, such as G.D, CNH Industrial, Pirelli Tyre and Solvay Specialty Polymers, which, despite being highly innovative, are not among the main players in green patenting. This comparison suggests that, although some large companies have already integrated sustainability into their technological approaches, there is still significant scope for expanding and strengthening the green orientation of Italian industrial innovation.

FIGURE 35

Advantage in terms of growth in added value and labour productivity of companies filing green patent applications vs companies filing non-green patent applications



Source: processing based on Dintec and ISTAT data

chap. 4

CASE STUDIES

NEXTCHEM/ MAIRE GROUP

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO WASTEWATER TREATMENT OR WASTE MANAGEMENT

ADDING VALUE TO RECYCLED PLASTIC: NEXTCHEM CLOSES THE LOOP AND STRENGTHENS MADE IN ITALY

In Italy, plastic recycling has achieved significant results thanks to increasingly widespread separate collection and a supply chain that has improved its technological capabilities and the quality of recovered materials in recent years. However, there are still some critical issues to be addressed: not all collected plastic can be recycled efficiently, some of it is sent for lower-value treatment, and difficulties remain in the management of multi-material packaging. The circular economy, on the other hand, cannot do without technologies capable of transforming plastic waste into quality resources suitable for replacing virgin polymers.

NextChem, a Maire Group company specialising in sustainable technological solutions, has met an ecological and economic need with a series of green patents supporting the energy transition and the circular economy, including biofuels, green hydrogen production, methanol and low-carbon ammonia, technologies for carbon capture and storage and for the recycling of end-of-life materials with a view to upcycling.

Among the latter, the NX-Replast™ patent developed by NextChem represents an innovation that has been appreciated in markets around the world. Plastic waste is inherently heterogeneous and arrives at plants in different shapes, colours, and compositions. This poses a problem both in the recycling process and regarding the quality of the final secondary raw material. The NX-Replast™ system accurately selects and separates polyethylene and polypropylene, eliminating impurities and unwanted components. The material treated in this way is of high quality, loses its status as waste and becomes 'end-of-waste', ready to be reintroduced into the industrial production cycle.

But this is not the only advantage offered by NextChem's technology. The recycled polymer is adapted to the specific needs of each customer thanks to the formulation capabilities developed by NextChem. This allows the company to offer products that are truly alternative to fossil polymers, with high performance and characteristics that can be customised to the needs of the end consumer.

Closing the loop around the end user is a competitive advantage that has made it possible to expand the range of target sectors for recycled polymer from automotive to packaging, from household appliances to public transportation seats and agricultural irrigation pipes, and thus expanding the number of customers – often global brands – not only in Europe, but also in Asia, the Middle East and South America. Becoming an international benchmark in the advanced recycling sector has not been easy, considering that producing recycled plastic in Europe is often more expensive than importing virgin polymers from the Middle East and Southeast Asia.

By focusing on the quality of the final product and on customisation around the end consumer, however, NextChem's technology has differentiated itself from the competition, proving to be 'market ready' and sustainable from both an environmental and an economic point of view. Know-how has become a powerful competitive asset that has strengthened the industrial positioning of Made in Italy on the one hand and, on the other, has become an enabler for a low-emission future.

The competitive advantages of using NextChem technology are also evident for end customers Having recycled plastic of high purity and technical quality allows them to completely replace virgin material in production or use a carefully studied mix, responding to a market that demands more sustainable and traceable materials, while improving their ESG indicators.

In terms of decarbonisation, the benefits of NextChem's patented technology are considerable. Using recycled polymers produced by NX-Replast™ reduces CO_2 emissions by more than 70% compared to the use of virgin polymers. Added to this is lower oil consumption and a reduction in waste sent to landfill or incineration. Last but not least, it allows the entire supply chain to enhance the value of citizens' efforts in separate waste collection, because without high-level industrial processes the selected plastic would risk not finding adequate market outlets, nullifying the system's efforts towards circularity.

CANDIANI DENIM

CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR PROCESSING OF GOODS

COREVA, THE SOLUTION THAT THE TEXTILE INDUSTRY HAS LONG BEEN WAITING FOR, OPENS UP NEW MARKETS

Every year, between 200,000 and 500,000 tonnes of textile microfibres end up in the oceans. A significant proportion of these come from the stretch garments we wear every day. Wash after wash, synthetic fibres release invisible but devastating plastic particles into the environment, accounting for up to 35% of the microplastics released into the marine environment.

It is precisely this awareness that has led Candiani Denim to change course. Although it has been internationally acclaimed for years for its stretch denim fabrics, the company has courageously addressed the environmental impact of synthetic fibres, which are widely used in the industry to ensure elasticity. Derived from petroleum, these fibres pollute during production and continue to do so by releasing chemicals, plastics and microplastics that are harmful to the environment and for humans.

This led to the creation of COREVA™, a fabric made from natural rubber that is entirely bio-based, biodegradable and compostable. It could have been just another bio-based solution like so many others in the textile industry. However, Candiani Denim's intuition did not simply replace one material with another with a lower impact: it solved an increasingly pressing problem and source of concern for consumers, namely the release of microplastics.

In addition to responding to the needs of the planet, the market was demanding a plastic-free product without compromising the quality, elasticity and durability of the fabric. Therefore, this unique technology was quickly adopted by the most innovative and environmentally conscious brands. The patent generated immediate value and opened up new markets and business segments for the owner company, not only in Italy but also in other European Union countries and in the United States, where the main buyers of COREVA™ are concentrated, with a positive impact on exports and the spread of Made in Italy.

Using Candiani Denim's technology is also a competitive advantage for the purchasing companies themselves, as it positions them in market segments with higher ESG value. Thus, they reduce the carbon footprint of their production activities, can claim to have more sustainable suppliers and can communicate that their final product has a lower environmental impact.

Now the most delicate phase has begun. After five years of research and development, Candiani Denim's goal is to make this technology scalable and apply it to different product lines to increase its offering and number of customers. For this to happen, however, time is needed and it is essential to remain competitive in the market. Therefore, COREVA™ technology is sold at a premium price to encourage its purchase until the new natural fibre reaches a scale of production that will allow it to replace current materials on a larger scale.

As proof of the interest generated, although the development of the COREVA™ patent was first entirely financed by Candiani Denim, the project has enabled the company to attract new capital and establish commercial and industrial partnerships that would not otherwise have been possible. This success has also strengthened employee confidence, with tangible benefits in terms of productivity. Indeed, internal cohesion is one of the main drivers of the company's growth.

Meanwhile, the patent has won several awards for innovation and sustainability. While the most significant economic benefits will be seen with large-scale use, the environmental benefits are already evident. Laboratory tests show that COREVA™ fabrics decompose in less than six months, turning into compost. Once biodegraded, the material becomes a soil conditioner that promotes plant growth and can be used to grow new raw materials for textile production. In this way, the patent is directly linked to regenerative agriculture and closes the production cycle: from soil to cotton, from cotton to jeans and, finally, from jeans back to soil.

UNIVERSITY OF MILANO-BICOCCA/ ITALIAN INSTITUTE OF TECHNOLOGY

SUSTAINABLE OCEAN ECONOMY

A SUSTAINABLE BIOMATERIAL FOR CORAL REEF RESTORATION BEATS THE COMPETITION TO THE PUNCH

The sea is in danger. Every year a little more. Its waters are warming, acidifying and emptying. Biodiversity is declining, and coastal communities are finding themselves increasingly vulnerable, caught between environmental crises and economic challenges. In this scenario, taking action is not an option, it is a priority. And those who can do so before others – with concrete, sustainable solutions that are ready to scale – will have a huge competitive advantage. Because when the emergency arises, having the answer ready means being in the right place at the right time with the right idea. This is what is happening in the field of technologies for the protection and sustainable management of marine resources, one of the fastest-growing sectors in green patents. This is not only an opportunity for innovation but an urgent necessity, capable of generating impact, value, and resilience.

Two centres of excellence in Italian research have been quick off the mark: the University of Milano-Bicocca and the Italian Institute of Technology. Together, they have developed a new generation of biomaterials and technologies – already the subject of a patent application – designed for the restoration of coral reefs. This is a fundamental step because reefs are not just natural wonders, they are vital infrastructure. They protect coastlines, host an extraordinary variety of marine species and support local economies. Restoring them helps communities and ecosystems to resist and adapt to the effects of climate change already under way, such as rising sea levels and warming waters.

But there is a significant obstacle: actively restoring coral reefs requires materials that promote the adhesion and growth of new colonies in damaged areas. The problem? The materials most commonly used today come largely from the petrochemical industry – the very industry that is fuelling the climate crisis – and can be harmful to the environment they are supposed to help save.

The patent developed by Bicocca, IIT (in collaboration with the Genoa Aquarium) solves two problems at once. The new material is biodegradable and non-polluting because it is made from two plant-based components. It also has a lower impact in terms of emissions: instead of high-carbon-footprint cements, coral reef restoration is carried out using a bio-based material made from agricultural waste such as maize, thus contributing to the spread of the circular economy.

The choice to use waste materials is also an advantage in terms of price. Biomaterial often fails to establish itself on the market because it cannot compete with cement. In this case, however, the fact that it is made from agricultural waste could keep costs affordable. The technology is still a prototype, and entrepreneurial initiatives will be needed to scale it up and verify real market demand.

Alongside the economic advantage, a second strategic strength emerges: research into biomaterials applied to the protection and sustainable management of marine resources, which is still in its early stages. The experiments, conducted at the Genoa Aquarium and in the Maldives at the MaRHE Centre (Marine Research and Higher Education Centre) – a Bicocca research centre set up specifically to test materials directly on coral reefs – offer the possibility for the patent holder to become a future point of reference for all nations wishing to take action to protect their coral reefs.

For Italy, the outlook is doubly positive. On the one hand, it represents an industrial competitive advantage because it allows the country to position itself among the world leaders in an emerging sector such as the blue economy and the protection of marine ecosystems. On the other hand, it opens up opportunities for application on our seabeds, for the conservation of Posidonia meadows, for the recovery of degraded habitats or for the protection of artificial barriers that defend ports and beaches. All this would protect not only the environment but also tourism in the country's coastal areas, a central part of the Italian economy.

RARA FACTORY

CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR PROCESSING OF GOODS

SHORTAGE OF RARE EARTHS? AN ITALIAN PATENT TO REPLACE THEM WITH OTHER MATERIALS

Rare earths are essential for many technologies – from permanent magnets to chips, from electric cars to smartphones – but their supply is unstable, expensive, and highly concentrated in a handful of countries. This dependence is now one of the most serious strategic vulnerabilities for European industry. This awareness has led to the creation of RARA Factory, a spin-off start-up from Ca' Foscari University in Venice, the result of collaboration between three researchers – an experimental materials physicist, a theoretical physicist, and a computer scientist. Thanks to patented technology based on artificial intelligence, it is able to identify alternative materials to rare earths that offer similar performance but with less environmental impact, lower costs and greater availability.

This innovative approach not only solves a technical problem but also opens up new opportunities for industrial autonomy and the development of a more sustainable and competitive Made in Italy. All the conditions are in place to conquer the market. The technology developed by RARA Factory embodies the qualities that make a patent take off: it addresses a concrete industrial problem, it offers a more economical solution, it paves the way for leadership in emerging markets and it helps reduce the carbon footprint and pollution of the rare earth extraction process. These are characteristics that speak to investors, who are attracted as much by the economic potential as by the environmental impact. Interest was not long in coming: several companies are currently considering investments in decarbonisation or have already entered into partnerships with RARA Factory to develop tailor-made alternative materials.

One of the aspects that gives the patent a highly competitive value is its versatility. Thanks to predictive models that combine network theory with generative artificial intelligence, the technology is able to analyse and test thousands of materials and combinations to identify those with the most promising properties.

The first area of application is magnetic materials – a sector currently dominated by neodymium, a rare earth element with a costly, fragile, and geopolitically unstable supply chain. The possibility of finding viable alternatives therefore represents not only a technological innovation but also a strategic step towards industrial autonomy and sustainability.

Finding magnets with similar characteristics but composed of common and abundant elements simultaneously reduces costs, emissions, and dependence on a single global production area. The industrial implications are enormous: permanent magnets are key components in electric motors, wind turbines, batteries, and electronic devices, in a market that is already worth over £60 billion and is set to grow with the energy transition.

However, the adaptability of the algorithm allows to include many other fields of application. The same methodology can also be applied to other sectors – from metals to polymers – to develop more sustainable and circular materials, such as alternatives to traditional plastics. Once the algorithm has been validated, the research becomes scalable and highly efficient, because the most expensive part, i.e., training the artificial intelligence, is amortised over time, allowing new materials to be designed at very low marginal costs.

The economic outlook is extremely promising: the newly discovered materials represent a strategic asset because their intellectual property remains with RARA Factory, which will be able to license it to various companies. The first industrial partnerships are already in place, with companies interested in securing exclusivity on key materials for sectors such as electronics, energy, and sustainable mobility.

But the real advantage is systemic: offering alternative solutions to rare and expensive materials means giving Made in Italy a unique opportunity to compete better – by lowering costs or reducing the carbon footprint – without sacrificing performance and quality.

IRONLEV

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO TRANSPORTATION

THE PATENT THAT BRINGS MAGNETIC LEVITATION TO EXISTING TRACKS REVOLUTIONISES RAIL MOBILITY

The decarbonisation of rail transport requires addressing one of its main structural inefficiencies: the mechanical interaction between wheel and rail. This contact generates friction and vibrations that have a significant impact on energy requirements, maintenance frequency and overall network performance. To make rail mobility truly sustainable, a systemic approach is needed that addresses the entire infrastructure, reduces mechanical stress, extends the life of the rails and improves service quality, especially in high-density urban areas.

This need is particularly relevant in Italy, where logistics is still skewed towards road transport and where the efficiency of the rail network is a critical factor. Delays are caused by infrastructure problems (34%), rolling stock failures (25%) and, increasingly, excessive traffic congesting the lines. Technologies capable of reducing wear and tear and failures and of increasing the effective capacity of the network therefore represent a potential turning point.

This is the direction taken by the patent developed by IronLev, regarding a passive magnetic levitation technology designed to operate on traditional tracks. The system uses permanent magnets and ferromagnetic components to generate a stable repulsive force capable of supporting the vehicle without consuming energy for lifting. The absence of physical contact eliminates rolling-rail friction, reducing mechanical stress on the infrastructure.

Compatibility with existing infrastructure is the main novelty of the patent. Unlike conventional maglev systems that require dedicated guides and significant investment, IronLev® operates on standard rails. No new tracks are needed and the emissions impact associated with steel production, a carbon-intensive process, is substantially reduced. Passive magnetic levitation eliminates wheel-rail friction and produces energy and operational benefits that go beyond simple power savings. Up to 100 km/h, efficiency increases by up to 30%. At higher speeds, the advantage is around 10% because aerodynamic drag becomes predominant.

The absence of contact allows for increased operating speed with the same power, resulting in shorter travel times. Since the technology is installed on the vehicle and does not require modifications to the line, it can be used on any route, including secondary lines and mountain railways. At the same time, less wear and tear on rails and mechanical components increases the reliability of the infrastructure. By reducing breakdowns and repairs, the network becomes less prone to interruptions or capacity reductions, with direct repercussions on traffic management. A network that wears less is more efficient, able to sustain higher volumes and reduces overcrowding.

The economic impacts of IronLev® technology follow the same logic. Infrastructure managers benefit from reduced scheduled and unscheduled maintenance, while railway operators can negotiate lower line usage fees due to the reduced stress on the rails. The combination of energy savings, shorter journey times on the most disadvantaged routes, reduced infrastructure costs and improved network reliability strengthens the overall competitiveness of rail transport and helps to bridge the historical gap with road transport, making it a truly cost-effective and sustainable alternative.

IronLev®'s competitive advantage is further consolidated by the fact that it is the only magnetic levitation solution that can be fully integrated into existing infrastructure. This has already attracted the interest of international operators such as Etihad Rail, RTA and several US players, who see the Italian patent as a viable route to rail decarbonisation without the prohibitive costs of traditional maglev infrastructure. Thanks to this innovation, Italy could become a European hub for sustainable magnetic levitation. Furthermore, the versatility of the patent can extend the benefits to many other production chains, with applications already in development in related sectors such as industrial handling systems, lifts, large doors and windows, and internal logistics solutions.

ITALCER

CAPTURE, STORAGE, SEQUESTRATION OR DISPOSAL OF GREENHOUSE GASES

CO_2 CAPTURE AND CONVERSION: THE PATENT TRANSFORMS EMISSIONS INTO NEW BY-PRODUCTS

The ceramics industry is considered one of the 'hard to abate' sectors because kilns operate at extremely high temperatures, consume large amounts of energy, and generate emissions that are difficult to eliminate. The margins for reduction seemed minimal until research opened up an unexpected path. Italcer, an Italian group active in high-end ceramics, has developed and patented a technology capable not only of almost completely eliminating emissions from its factories but also of transforming them into new raw materials with high added value, generating new market opportunities and a significant competitive advantage.

Italcer's patent is based on a system for capturing and transforming exhaust gases from production plants. CO_2 and other compounds emitted by the kilns are separated and converted into secondary raw materials that can be used directly in the group's production lines. The precipitated calcium carbonate (PCC) obtained from CO_2 is a 'noble' material, widely used in the pharmaceutical and cosmetics industries. The other gases absorbed are transformed into calcium nitrate, useful as a fertiliser in agriculture, potassium sulphite, an antioxidant used in the food industry, and gypsum. These raw materials are obtained 'locally', without procurement or transport costs and with virtually no environmental impact.

The strength of the technology is twofold: it decarbonises a highly energy-intensive sector and, at the same time, opens up new lines of business. Surplus secondary raw materials can be sold to external industrial sectors, while the patent itself can be licensed to related industries such as glass, bricks, construction, and automotive, making Italcer a potential supplier (or licensor) of a replicable and scalable technology in the main hard-to-abate sectors.

The environmental benefits of the technology are considerable. In addition to the almost total elimination of furnace emissions, the process further reduces internal impacts and emissions because it recovers 2,000 litres/hour of water from the fumes and 750 thermal kW/hour of heat, which is not dispersed but returns to the production cycle as energy. Furthermore, precipitated calcium carbonate is a high-quality excipient that is highly sought after on the market but is obtained through high-temperature processes, which in turn consume enormous amounts of energy and produce carbon dioxide. The precipitated calcium carbonate produced by Italcer, on the other hand, is derived from CO_2 already emitted by the ceramic process, thus abating both the emissions of the chemical industry due to traditional production and those of the ceramic factory.

With the start-up of the first plant, Italcer will be able to generate approximately 10,000 tonnes per year of new secondary raw material and avoid over 5,000 tonnes of carbon dioxide. The economic prospects are equally significant: up to €100 million in additional revenue and approximately €30 million in ETS savings over 6-7 years. This is a rare case in which an environmental cost becomes an industrial asset, when green technology that reduces climate impact creates new markets and strengthens the company's competitive position in a highly challenging global sector.

It is not surprising that the European Union has supported the project with over €4 million in funding, recognising its transformative potential. To date, there are no equivalent solutions at international level. Italcer has been contacted by various companies in the sector for possible collaborations and thus has the opportunity to position itself as a technological player in a particularly competitive market such as that of sustainable materials production, helping to define new standards for the decarbonisation of the ceramic industry and other hard-to-abate industrial sectors.

ICAR-CNR – UNIVERSITY OF CALABRIA - ECO-4CLOUD

CLIMATE CHANGE MITIGATION IN INFORMATION AND COMMUNICATION TECHNOLOGIES (ICT)

THE PATENT THAT REDUCES DATA CENTRE CONSUMPTION BY UP TO 60%

The boom of data traffic, cloud computing and artificial intelligence is transforming data centres into one of the most energy-intensive infrastructures of the digital transition. Today, they consume around 1.5% of global electricity and, according to estimates by the International Energy Agency, this could rise to just under 3% by 2030, with demand growing from around 415 TWh in 2024 to around 945 TWh in 2030. Added to these figures is another critical factor, namely the energy required for cooling and, increasingly, for water consumption management. In this context, improving efficiency is not only an environmental choice but a direct competitive lever for data centre owners and cloud providers, because energy is now one of the most significant cost items.

The technical paradox that gives rise to the problem is well known. Due to structural limitations of hardware and virtualisation, servers operate at an average of 20-30% of their capacity but, even at these reduced loads, they continue to consume around 70% of the energy required at full utilisation. The result is that a significant portion of the electricity entering a data centre does not actually support computational work but feeds an almost constant 'base-load', amplified by cooling systems.

Today's most common solutions attempt to mitigate this inefficiency with decentralised mechanisms that monitor servers and continuously move applications and virtual machines from one node to another. But local optimisation often produces a side effect: too many simultaneous migrations, greater management complexity and energy results that are far from optimal overall.

The patent developed by ICAR-CNR researchers – subsequently transferred to the spin-off Eco4Cloud – tackles the problem at its root with an intelligent virtual machine consolidation algorithm. The logic is simple but powerful: concentrate loads on the minimum number of servers necessary, so that inactive nodes can be shut down or put on standby. The idea exploits a structural feature of the hardware, i.e., reducing the load on a single server slightly decreases consumption, while shutting it down significantly reduces it. In tests, this strategy generated energy reductions of between 30% and 60%, with proportional savings in emissions.

The environmental effect is immediate and twofold. On the one hand, less electricity consumed by servers means fewer emissions associated with the energy mix. On the other, reducing IT power automatically reduces cooling requirements – one of the most energy-intensive components of any data centre – thereby improving the overall efficiency of the infrastructure.

The economic benefits follow the same dynamic: cutting consumption has a direct impact on operators' bills, which for large data centres can be worth millions of euros per year. Even in the most conservative scenarios, operational savings remain in the order of 10-20%, and the reduction in active servers reduces both hardware requirements and the size of the cooling systems needed, with advantages also in terms of initial investment.

The reason why the technology has attracted the interest of players such as HP and VMware is its immediate integrability. Eco4Cloud does not require physical intervention on the infrastructure but plugs directly into the existing virtualisation layer, operating via standard APIs with the main platforms (such as VMware vSphere and Microsoft Hyper-V). This makes it 'market ready' and ready to scale at a time when AI is multiplying computing loads. Since optimisation takes place at the virtual machine layer, the principle remains valid from traditional clouds to HPC centres to data centres dedicated to artificial intelligence, where energy efficiency is now a technical as well as an economic constraint. The validity of the solution is demonstrated by its adoption in data centres of major Italian operators such as Telecom Italia and Engineering.

REM TEC

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO ENERGY GENERATION, TRANSMISSION OR DISTRIBUTION

AGRIVOLTAICS COMBINES FOOD AND ENERGY AND MAKES ITALY ONE OF THE LEADERS IN RENEWABLES

Producing energy without taking land away from agriculture is one of the challenges of the green transition. For years, more photovoltaics has meant fewer fields, fewer crops, and less production. It is precisely in an attempt to overcome this limitation that REM Tec's intuition was born, i.e., to transform agricultural land into a dual production system, capable of generating food and energy simultaneously. This vision has given rise to Agrovoltaico® technology, an Italian patent that is now one of the most advanced models in the world, capable of combining and optimising energy production from renewable sources and agricultural production.

The added value of this patent in terms of competitiveness lies in its effective integration of two fundamental requirements: environmental and economic sustainability, with documented results in terms of efficiency, competitiveness, and sustainability. It maximises soil yield, improves agricultural productivity, reduces operating costs and generates a dual income stream from energy and from crops.

At the heart of the innovation is a biaxial solar tracking system installed on a structure raised to a height of approximately 4.5 metres. The panels, which can be adjusted independently, modulate light and shade on the ground below in real time. It is this dynamic control that makes Agrovoltaico® different from any traditional photovoltaic system: shade is no longer a side effect but becomes an agronomic tool. Research conducted with the Catholic University of Piacenza, CNR and other institutes has shown that many crops – including table grapes, cereals, horticultural crops and medicinal plants – improve in yield and quality when protected from excessive radiation during critical stages. Intelligent shade management reduces evapotranspiration, lowers water consumption, and increases resilience in drought conditions.

The economic results confirm the potential. Farms that adopt Agrovoltaico® see income increases of up to 18%, while trials on high-value crops show productivity increases of up to 25%. At the same time, the system produces renewable energy without taking land away from agricultural activities, generating a second income stream and improving the financial stability of farms. The structure is prefabricated, lightweight, recyclable and completely removable and, above all, does not permanently alter land use, which is a decisive requirement for compliance with European standards and the new CAP.

It is a decisive factor in promoting the spread of renewable sources because by making photovoltaics fully compatible with agricultural activity, the installable area is expanded, investments are accelerated and a direct contribution is made to the decarbonisation of the energy system and the increase in biodiversity. In addition to the energy produced by solar panels, agricultural land also generates biomass, and therefore Agrovoltaico® contributes to further increasing the share of renewable sources in the energy mix.

LCA analyses conducted by ENEA highlight superior environmental performance compared to ground-mounted photovoltaics, since the greater use of materials is offset by the multifunctionality of the system and the improvement of ecosystem services. The potential of the technology has been evident since the first systems were built by REM Tec in 2011, among the first operational examples of advanced agrivoltaics in Europe. Since then, its progressive spread in Italy, France, China, Japan, Portugal and Israel demonstrates the scalability of the solution and the international recognition of Italian know-how. With the global spread of photovoltaics and the growing demand for multifunctional systems, Agrovoltaico® opens up new opportunities for the export of components, engineering services, design and industrial licences.

DIASEN

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO BUILDINGS

DIATHONITE®, THE CEMENT-FREE INSULATING CORK-BASED PLASTER THAT MAKES BUILDINGS MORE SUSTAINABLE

The construction industry is currently undergoing increasing pressure. In Italy alone, according to Legambiente-Kyoto Club data, the sector accounts for 27.9% of energy demand and 24.2% of climate-changing emissions. Most of the environmental impact is linked to the carbon incorporated into buildings, i.e., the materials used to construct them: cement alone is responsible for 8% of global CO_2 emissions (IEA data). This impact is set to increase in the future, driven by urbanisation and the consequent growth in the consumption of building materials.

In recent years, new products have been emerging that attempt to reduce the carbon footprint of materials and ensure greater energy efficiency in buildings through thermal insulation. This is where Diasen comes in with Diathonite®, a line of patented premixed mortars and plasters based on cork, natural lime, clays and natural aggregates. Thanks to its formulation – cement-free and composed of renewable or natural raw materials – Diathonite® significantly reduces environmental impact compared to traditional plasters.

Cement production has a high carbon footprint due to the high temperatures required for the process. Although Diathonite® mortars require energy for processing, they mainly use natural materials with a significantly lower carbon content. Cork, in particular, comes largely from waste from the production of corks, which for production reasons cannot be used in the wine industry: their use in construction therefore activates a circular economy that would otherwise be difficult to achieve. The raw material comes from the oak forests of Sardinia, which account for 3% of the world's reserves and support a supply chain that is currently weakened by competition from Spain and Portugal, which alone account for 80% of global production.

Procurement from forests also contributes to decarbonisation, as cork is obtained by removing the bark without felling the trees that therefore may continue to perform their function of absorbing greenhouse gases.

Added to this are the environmental benefits of replacing panel insulation materials, often made of polypropylene, a plastic that requires fossil fuels.

Cork is therefore the product's main competitive asset. Its highly porous structure promotes the presence of air in the internal cavities. The result is effective thermal insulation in winter and especially in summer, with a reduction in cooling consumption, and natural humidity regulation thanks to its high permeability, which keeps walls dry and prevents mould and condensation. The material is fire-resistant, lightweight due to the aggregates present in the matrix – a feature that facilitates installation – and has mechanical strength that guarantees stability, durability over time and excellent acoustic insulation performance. These properties make the plaster extremely versatile. It can be applied indoors and outdoors, on traditional masonry, damp walls or buildings undergoing renovation, and is effective in the restoration of historical buildings thanks to its lightness and breathability, as demonstrated by the work carried out on the Royal Palace of Évora in Portugal.

These are all huge advantages from a competitive point of view. For a builder, choosing Diathonite® means focusing on natural, long-lasting raw materials, eliminating the need for complex internal insulation or external cladding systems, and with thermal and acoustic insulation already integrated. This streamlines the supply chain, reduces the consumption of additional materials and simplifies design in cases where the use of panels would be complicated, such as in the presence of curved surfaces. One example was its application in the construction of several Paris metro stations.

For Diasen, the Diathonite® product line allows it to clearly distinguish itself from the competition, offering solutions that combine high technical performance with reduced environmental impact: a strong incentive for all companies committed to decarbonising their activities and complying with ESG criteria. The 'Green Homes' directive, which introduces energy efficiency and emissions reduction requirements in buildings, is set to further expand this market, creating new opportunities for materials such as Diathonite® that meet both requirements. The success of the material proves this, with a growth rate of 20% and an estimate that confirms the trend will continue through 2026.

MAGALDI

CLIMATE CHANGE MITIGATION TECHNOLOGIES RELATED TO ENERGY GENERATION, TRANSMISSION OR DISTRIBUTION

MGTES, THERMAL STORAGE BATTERIES DECARBONISE INDUSTRIAL PROCESSES

The green transition needs new solutions to overcome the limitations that are currently slowing down industrial decarbonisation. Two of these challenges are decisive and still unresolved: sustainable heat production – essential in many production processes and one of the main sources of emissions – and energy storage, necessary to ensure the constant availability of energy produced from renewables, which by their nature cannot be programmed. These are two different but closely related problems.

A solution developed in Italy could solve both critical issues within this technological space. Magaldi, a long-established Italian company with consolidated know-how in storage, has patented MGTES (Magaldi Green Thermal Energy Storage), a system that stores energy from renewable sources in the form of heat and returns it up to over 600°C, making it directly usable in industrial cycles.

The need it fills is enormous. Heat accounts for over 70% of industrial energy consumption and in 90% of cases is still produced by burning fossil fuels. This is a particularly difficult area to decarbonise, especially in the temperature ranges typical of many manufacturing sectors such as paper, chemicals, food & beverage, and mining (150-400°C), where direct electrification is complex and low-carbon alternatives are still limited. At the same time, the growth of solar and wind power sourcing has increased the availability of clean energy but without solving the problem of non-programmability. Storage is thus needed to provide balancing services to the electricity grid and release energy when needed, especially in the form of high-temperature heat, a task that electrochemical batteries cannot perform.

The MGTES patent addresses both issues with an engineering solution that is simple and robust. At the heart of the system is a bed of fluidised sand, a common material that is ideal for storing thermal energy in a stable and safe manner. During charging, electricity from renewables heats the sand via immersed heating elements. During storage, strong insulation minimises heat loss and increases overall efficiency. During discharge, the energy is transferred to a heat transfer fluid and released as steam or direct heat, ready to power industrial processes without intermediate conversion.

The impact on decarbonisation is direct: replacing gas and diesel in thermal processes with renewable heat reduces industrial emissions, cuts dependence on fossil fuels and lowers ETS costs related to carbon credits. Storage efficiency also reduces the primary energy required to deliver the same thermal output. Added to this are indirect but decisive benefits, i.e., MGTES uses recyclable and non-critical materials (silica sand and steel) without the need for rare earths and eliminates the fire risks typical of batteries. The first plant under construction is estimated to reduce the factory's energy consumption by 20% and approximately 1,000 tonnes of CO_2 per year when fully operational.

However, it is the combination of environmental and economic advantages that explains the competitive strength of the patent. The absence of critical materials eliminates supply risks and price volatility, while the inert nature of sand makes the technology easier to authorise and manage than electrochemical storage. Installation and maintenance costs remain low thanks to the simplicity of the materials and of the technical solution.

The patent also offers another strategic advantage: cross-sectional scalability. The system is modular, compact and can be integrated even into plants with limited space. In other words, Magaldi has not only developed a storage system but a globally replicable industrial platform capable of accelerating the transition precisely where it is most difficult today.

IDRA GROUP

CLIMATE CHANGE MITIGATION TECHNOLOGIES IN THE PRODUCTION OR PROCESSING OF GOODS

GIGA PRESS PRODUCES ONE CAR BODY PER MINUTE AND CUTS COSTS BY 40%

One of the main obstacles to the electrification of transport is the high price of cars. Traditional car body assembly, based on dozens of pressed and welded metal sheets, is currently one of the main limitations to the competitiveness of electric vehicles because each car body is the result of 70-80 different components, requires long production processes and a high amount of energy, and involves operating costs that are difficult to reduce.

For this reason, the Giga Press developed by the Brescia-based Idra Group introduces a technology to the automotive sector that can make its mark on the market: the machine is capable of casting a single aluminium casting that shapes the entire front or rear section of the body, replacing assemblies consisting of dozens of stamped and welded components. This eliminates numerous joints, shortens the production chain and, above all, increases plant productivity, with the overall effect of reducing time and costs for each vehicle.

Conventional presses were unable to guarantee the clamping force and thermal control necessary to cast large volumes of molten aluminium without generating defects. The Giga Press already existed as a concept, but the quantum leap came with the Idra Group's patent that introduced 5S injection technology, a high-speed, high-pressure system that stabilised one of the most critical steps in die casting and made it possible to cast uniformly over such large surfaces, simplifying the entire process and improving its reliability.

Thanks to the patent, Idra Group has succeeded in developing a machine capable of exceeding 9,000 tonnes of clamping force and injecting over 100 kilograms of aluminium alloy into moulds the size of a car body. The final high-pressure compaction phase stabilises the cast and seals the mould, preventing any metal reflux. The result is made possible by precise control of the mould temperature – guaranteed by integrated cooling and temperature control systems – and by a powerful injection unit equipped with real-time sensors that modulate pressure and speed to ensure uniform, reliable filling that complies with the standards required by the automotive industry.

The key aspect that has made the patent competitive is the way it combines high speed (and therefore productivity) with repeatability. In the factories where the Giga Press has been installed, production cycles allow around 6,000 parts to be produced per week, or one car body every 60-90 seconds. Single-piece casting generates enormous advantages from a production point of view. Reducing the number of body parts from dozens to just one allows for shorter production lines and fewer welding robots, thereby reducing energy consumption by 50% as well as waste and factory space occupied. Overall, costs can be cut by 40%.

In addition to the economic benefits, there are also environmental benefits. A faster process with fewer components means less raw material, less processing and lower energy consumption, and therefore lower CO_2 emissions. Furthermore, the use of the Giga Press may encourage the adoption of aluminium by car manufacturers who have used only steel until now. While the advantage of aluminium is that it is a very light material, at the same time it is extremely energy-consuming. Fortunately, however, it can be recycled indefinitely without losing quality, and the body can be made entirely from recycled material.

Until now, the main obstacle has been the higher costs and complexity of industrial processes, but single-piece casting makes aluminium processing more efficient and competitive. In addition, the Giga Press machine incorporates a system for recovering aluminium alloy scraps and waste, which are immediately reintroduced into the casting cycle, further reducing raw material consumption. Finally, the systemic effects must be considered, because it is an enabling technology for the spread of electric cars and therefore accelerates the decarbonisation of transport.

To vehicle manufacturers the adoption of Idra Group's Giga Press offers an immediate competitive advantage: it reduces industrial costs, allows for increased production volumes, lightens car bodies and makes it possible to offer more price-competitive models. For Idra Group, the technology developed represents a unique position in the market, because thanks to its patent it has made presses capable of producing monolithic bodies more productive and less expensive. This has attracted the interest of major automotive groups in the United States and Asia, and now also in Europe. Indeed, the technology can be applied not only to pure electric vehicles but also to hybrid and mild hybrid models that are more common in Europe.

The automotive industry is entering a new phase, since production efficiency is a strategic necessity and the automotive industry wants to avoid dependence on Chinese technologies at all costs, as has happened in other sectors. That is why Idra Group has transformed a technical limitation into a competitive advantage and today Italian manufacturing can play a leading role in the new electric vehicle economy.

APPENDIX

A1

Hierarchical scheme of Environment-related technologies OECD

1 **ENVIRONMENT**

1.1 **Environment-related Technologies**

Generic environmental technologies, the broadest category. It includes over 95% of Environment-related patents.

Subcategories:

1.1.1 **Environmental Management**

Pollution control (air, water, soil)

Waste management

Environmental monitoring

1.1.2 **Climate Change Mitigation Technologies**

Technologies to reduce greenhouse gas emissions

This subcategory is further divided into seven sectoral areas:

1.1.2.1 **Energy generation, transmission or distribution**

Renewable energy, smart grids, hydrogen, energy storage

1.1.2.2 **Transportation**

Electric/hybrid vehicles, alternative fuels, aerodynamic efficiency

1.1.2.3 **Buildings construction**

Thermal insulation, heat pumps, home automation for energy efficiency

1.1.2.4 **Wastewater treatment or waste management**

Technologies for wastewater treatment and sustainable waste management

1.1.2.5 **ICT (Information and Communication Technologies)**

Digital technologies to reduce consumption and optimise resources

1.1.2.6 **Production or processing of goods**

Industrial innovations to reduce emissions in production cycles

1.1.2.7 **Capture, storage, sequestration or disposal of greenhouse gases**

CCS (carbon capture and storage), direct CO_2 sequestration, etc.

1.2 **Climate Change Adaptation Technologies**

Technologies that reduce vulnerability to climate change. Examples: resilient infrastructure, climate-resilient agriculture, advanced irrigation systems, predictive environmental monitoring.

1.3 **Sustainable Ocean Economy**

Technologies for a sustainable blue economy.

Examples: marine energy (waves, tides), responsible fishing, marine ecosystem monitoring, ocean protection technologies.

A2

To estimate the relationship between green orientation and business performance, an ordinary linear regression (OLS) model was applied with the following specification:

$$\Delta \ln(y_i) = \alpha + \beta\, flag_{green_i} + \sum_k \gamma_k X_{ik} + \varepsilon_i$$

where:

- $\Delta\ln(y_i)$ rrepresents the logarithmic variation (2017–2022) of the performance variable: – in the first model, the added value (dln_vagg), – in the second, labour productivity (dln_lp);
- flag_green is a binary variable that takes the value 1 if the company has filed patents in environmental technologies, 0 if the company has filed patents in other technologies;
- X_{ik} is the control vector that includes:
- **territorial area** (C(carea)),
- two-digit ATECO **economic activity sector** (C(ateco2)),
- **size class** (C(cladd)),
- **proportion of graduates** out of total employees (lauquota),
- **proportion of STEMplus graduates** out of total employees (STEMplus_quota),
- **foreign participation indicator** (flag_g).

Categorical variables were introduced as **dummies** (fixed effects) to control for structural and sectoral heterogeneity, while quantitative variables were included in continuous form. Estimates were made using classical (non-robust) standard errors and include a total of approximately **6,000 observations** for the added value model and **5,700** for the labour productivity model.

The significance of the coefficient associated with the green variable provides robust evidence of a positive relationship between the environmental orientation of innovation and business growth.

The control variables relating to STEMplus skills show a positive and significant impact in the first model, while foreign participation and the proportion of graduates are not statistically significant. Overall, the estimates confirm that sustainability-oriented innovation is associated with greater capacity for growth and improved production efficiency in the medium term.

TABLE 1

Effect of green innovation on the economic performance of businesses (2017–2022)

	(1) Added value growth	*(2) Labour productivity growth*
Green innovation (flag_green)	0.109 **	0.054 *
	(0.045)	(0.031)
Quota of graduates (lauquota)	−0.057	−0.006
	(0.097)	(0.066)
Quota of STEMplus employees (STEMplus_quota)	0.682 ***	0.056
	(0.125)	(0.085)
Employee class = 2[1]	0.000	−0.049 **
	(0.031)	(0.021)
Employee class = 3[1]	−0.073	−0.041
	(0.044)	(0.030)
Foreign participation (flag_g)	−0.021	−0.028
	(0.029)	(0.020)
Fixed effects: Area	Sì	Sì
Fixed effects: Sector (ATECO 2)	Sì	Sì
Fixed effects: Employee class	Sì	Sì
Comments (N)	5,963	5,746
R^2	0.041	0.021

*Notes: non-robust standard errors in round brackets. * p<0.10; ** p<0.05; *** p<0.01.*

[1] Reference category: Employee class = 1. (Area and sector dummies are included but not reported.)