

PATENT ACTIVITY IN THE FIELD OF PHOTOVOLTAICS

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Abstract

Renewable energy production technologies are finding increasing application in the context of the problems and environmental threats associated with conventional resources. There is a growing interest in the development of environmentally friendly renewable energy sources, including photovoltaic systems.

The aim of the report is to examine patent activity in the field of photovoltaic technologies, focusing on the rights granted by the European Patent Office (EPO) to innovative developments. Through the application of empirical methods, the latest trends of technological changes in the field of photovoltaics have been traced and an analysis of patent activity carried out in the EU-27 countries for the period 2010-2022 has been prepared.

Keywords: patent; patent activity; Photovoltaic (PV) technologies.

INTRODUCTION

Renewable energy production technologies are increasingly being used in the context of the problems and environmental threats posed using conventional resources. Increasing the share of renewable energy is one of the measures to combat global warming, which predetermines the growing interest in developing environmentally friendly renewable energy sources, which include photovoltaic systems.

The subject of research in the report is photovoltaic technologies.

The subject of research is the patent activity carried out by patent proprietors through the European Patent Office (EPO) in the period 2010-2022.

The purpose of the report is reduced to an analysis of patent activity in the field of photovoltaic technologies, focusing on the rights granted by the European Patent Office on innovative developments. The objective thus defined is achieved by solving the following **tasks**:

- justifying the choice of patent statistics as an indicator of

technological developments in the field of photovoltaics.

- presentation of the priority IPC classes for development among photovoltaic technologies.
- research on patent activity in the field of photovoltaic systems carried out through the EPO for the period 2010-2022

A **graphical method** and a **method of comparison** were used to present the results of the study.

The analysis is **limited** to the patent activity data provided by the EPO.

PATENT STATISTICS AS AN INDICATOR OF TECHNOLOGICAL CHANGE

The development of society is supported by the intellectual activity of several inventors whose scientific and technological developments give the image of modern times. The importance of intellectual products requires the creation of regulations to protect the rights of their owners against their unlawful use by third parties – intellectual property legislation is created.

The complexity of each of the objects of intellectual property predetermines the existence of a specific legislative framework at national, regional, and international level, specifying the legal protection for the subject-matter concerned.

One of the most significant for the development of society objects of intellectual property are inventions. Evidence of the existence of legal protection over an invention is the patent granted for it, representing “...an exclusive right granted for an invention (a product or a process that provides a new way of doing something, or offers a new technical solution to a problem)” [1, p.18].

The territorial nature of patent protection predetermines the need to extend it at regional or international level through the treaties and conventions signed in the field for the protection of inventions abroad. This is necessary, *firstly* – to ensure the transfer of technology and stimulate human development and, *secondly*, to extend the economic benefits to the patent owner from the exploitation of the rights in the patented invention. “One of the basic rationales of the patent system is to provide an incentive for the creation of new technology and inventions by offering inventors exclusive rights to commercially exploit patented inventions for a limited time”. [2, p.9]

Patents are also a source of information on technological developments in each field. This arises from the statement, “... that the knowledge contained in patent documents is technological knowledge (technological information), since it possesses all three characteristics of the concept of “technology” [3, p. 32]. In turn, technology as a concept according to Ahnell & O’Leary represents “the scientific study and practical

application of the industrial arts, applied sciences, etc., or the method for handling a specific technical problem” [4, p.1]. According to the World Intellectual Property Organization (WIPO), the main features of the concept of “technology” are:

- A set of systematic knowledge to ensure the solution of a problem.
- This knowledge must exist in a certain place, be disclosed, and be able to transmit it from one person to another.
- Knowledge must have applications in industry, agriculture, or commerce [3, p.32].

The technological information contained in patent documents can stimulate inventive activity, as patent descriptions of inventions reveal the essence of innovative technologies. Patent information is also the most comprehensive and valuable source of knowledge about existing legally protected technologies [5, p.12].

The nature of patents described so far, and the outlined characteristics of technologies predetermine the role of patent statistics as one of the most used indicators for measuring the results of scientific and technological activity and as an indicator of technological changes in the economy.

DEVELOPMENT OF PHOTOVOLTAIC (PV) TECHNOLOGY IN EUROPE

One of the areas in which theorists and practitioners have shown increased interest in recent years in the context of the European Green Deal and the strong pursuit of reducing harmful emissions into the environment is that of renewables. Of interest for the present analysis are photovoltaic systems as an unconventional source of energy and as an environmentally sound technology.

Table 1. Range of photovoltaic environmentally sound technologies [7]

PHOTOVOLTAICS (PV)	IPC CODE
Devices adapted for the conversion of radiation energy into electrical energy:	H01L 27/142, 31/00 - 31/078 H01G 9/20 H02S 10/00
- Using organic materials as the active part	H01L 27/30, 51/42-51/48
Assemblies of a plurality of solar cells	H01L 25/00, 25/03, 25/16, 25/18, 31/042
Silicon; single-crystal growth	C01B 33/02 C23C 14/14, C23C 16/24 C30B 29/06
Regulating to the maximum power available from solar cells	G05F 1/67
Electric lighting devices with, or rechargeable with, solar cells	F21L 4/00 F21S 9/03
Charging batteries	H02J 7/35
Dye-sensitised solar cells (DSSC)	H01G 9/20 H01M 14/00

According to the Committee of Experts of the International Patent Classification (IPC), which structures the indices for the classification of patents by fields of application of environmentally sound technologies [6], the scope of photovoltaics includes the following IPC indices presented in Table 1.

Based on the proposed IPC codes (Table 1), an analysis of the information in the European Patent Office (EPO) - *PATSTAT database* has been prepared. *PATSTAT* [8] contains data on European patent applications and granted European patents, together with patent information on the nature of the technology applied for or already protected.

The data obtained from the analysis (Table 2) show the requesting activity carried out through the EPO for which data are available in *PATSTAT* without the time limit of the study being introduced.

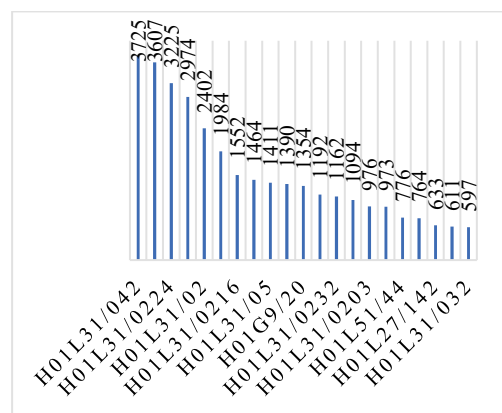
Table 2. Total application in EPO by IPC code

IPC CODE	TOTAL APPLICATIONS
H01L 27/142, 31/00-31/078 H01G 9/20 H02S 10/00 H01L 27/30, 51/42-51/48	25 686
H01L 25/00, 25/03, 25/16, H01L 25/18, 31/042	7 146
C01B 33/02 C23C 14/14, 16/24 C30B 29/06	3 334
G05F 1/67	488
F21L 4/00 F21S 9/03	674
H02J 7/35	1 244
H01G 9/20 H01M 14/00	2005

Source: PATSTAT / Authors' calculation

Following each of the directions of application of the studied technologies (see Table 1 and Table 2), the increased applicant interest in technologies applied in the field of „Devices adapted for the conversion of radiation energy into electrical energy“ (see Figure 1) has to index **H01L 31/042 PV modules or arrays of single PV cells (supporting structures for PV modules H02S 20/00)**. It is contained in 3725 of the applications filed or 14.51% of all invention applications in this field.

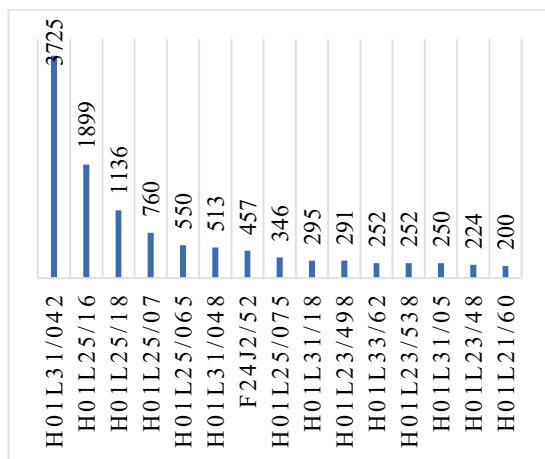
Next of research interest are technologies including index **H01L 31/18 Processes or apparatus specially adapted for the manufacture or treatment of these devices or of parts thereof** with 3607 applications which also specify 14.05% of the total applicant activity. In third position is **H01L 31/0224 Electrodes** (3225 applications and 12.56% share).



Source: PATSTAT / Authors' calculation

Fig. 1. Top 20 IPC classes in the field of „Devices adapted for the conversion of radiation energy into electrical energy“

In the field of application of environmentally sound technologies „Assemblies of a plurality of solar cells“ (see Figure 2), the applicants are most interested again in **H01L 31/042 PV modules or arrays of single PV cells (supporting structures for PV modules H02S 20/00)**, included in 52.13% of applications. As this information shows, the IPC classification index can be attributed to different technologies, depending on their purpose.

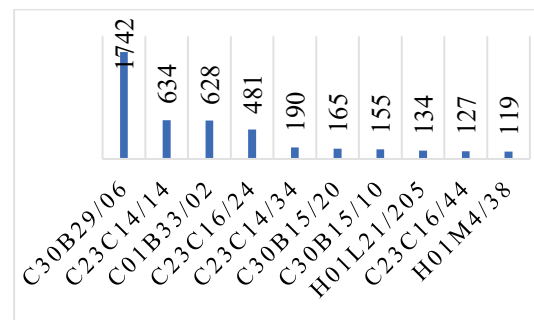


Source: PATSTAT / Authors' calculation
Fig. 2. Top 15 IPC classes in the field of „Assemblies of a plurality of solar cells“

In second position is index **H01L 25/16 the devices being of types provided for in two or more different main groups of groups H01L 27/00-H01L 33/00, or in a single subclass of H10K, H10N, e.g. forming hybrid circuits**, specified in 26.57% of applications. **H01L 25/18 the devices being of types provided for in two or more different subgroups of the same main group of groups H01L 27/00-H01L 33/00, or in a single subclass of H10K, H10N**, are in third position, and are included in 15.9% of applications for patenting.

Analyzing applications for patenting technologies related to the application area “Silicon; single-crystal growth” (see Figure 3), 52.25% of applications contained the **C30B 29/06 Silicon** index and 19.02% contained the **C23C 14/14 Metallic material, boron, or silicon** index. In 18.84% of the applications, the **C01B 33/00 Silicon Compounds thereof (C01B 21/00, C01B**

23/00 take precedence; persilicates C01B 15/14; carbides C01B 32/956) index is indicated.



Source: PATSTAT / Authors' calculation
Fig. 3. Top 15 IPC classes in the field of “Silicon; single-crystal growth”

The technologies applied in the field “Regulating to the maximum power available from solar cells” include only one IPC index – **G05F 1/67**, which participated in 488 applications.

In the direction “Electric lighting devices with, or rechargeable with, solar cells”, the IPC indices assigned to this technology are present in a total of 674 patent applications, and the first in research interest is the **index F21S 9/03 rechargeable by exposure to light** with 34.87%.

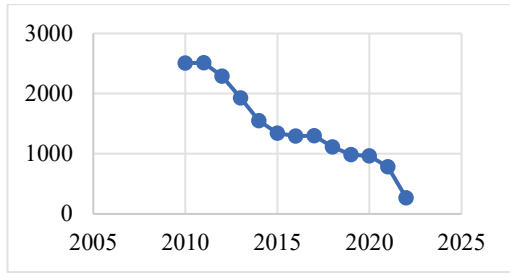
In the area for the application “Charging batteries” with an index **OF H02J 7/35** are requested 1244 technologies for patents.

In the area “Dye-sensitised solar cells (DSSC)” the **H01G9/20** is of greatest interest, with 67.53% of the requests including this index.

PATENT ACTIVITY IN THE FIELD OF PHOTOVOLTAIC SYSTEMS FOR THE PERIOD 2010-2022

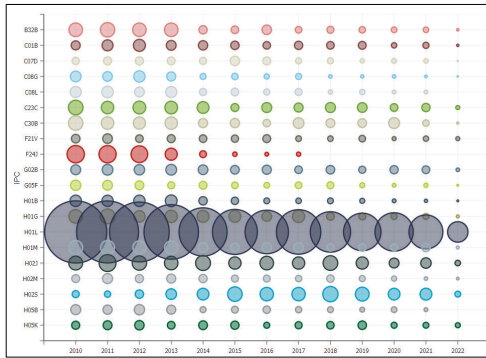
Patent applications filed

Analyzing the total applicant activity in the field of photovoltaics, the data obtained through *PATSTAT* express a negative downward trend in the applicant activity in this area. For the period 2010-2022, there is a decrease in the number of applications for environmentally sound technologies in the field of photovoltaics, an average annual by 14.5%. (see Figure 4).



Source: PATSTAT / Authors' calculation
Fig. 4. Dynamic of total patent application for the period 2010-2022

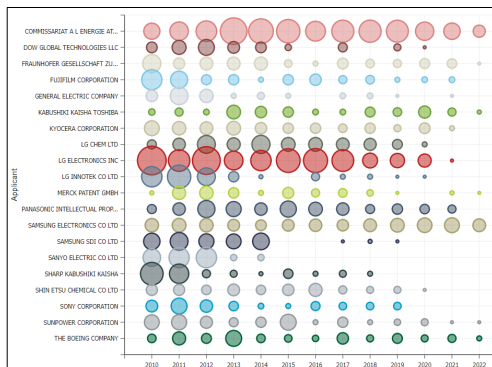
Comparing the applicant activity by year and by IPC classes (the first 20 classes of the surveyed) included in the scope of photovoltaic environmentally sound technologies (see Table 1), decreasing applicant activity also stands out on each of the classes studied (see Figure 5).



Source: PATSTAT / Authors' calculation
Fig. 5. Patent applications in the top 20 IPC classes in the field of PV technologies

Concentration of applicant activity is reported by **index H01L**, followed by **C23C, H02J** and **C30B**.

Information on the company's filing the patent applications is disclosed in Figure 6.



Source: PATSTAT / Authors' calculation
Fig. 6. Patent applicants

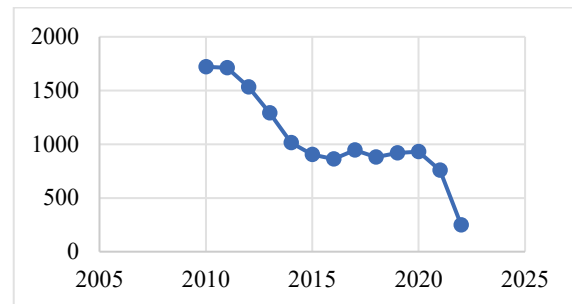
In addition to the applicants, the figure is also indicative of the leading companies in the field of photovoltaic technologies, which have a concentration of patent rights, as follows:

- Commissariat A L Energie Atomique Et Aux Energies Alternatives – 674 patent applications.
- LG Electronics Inc. – 619 applications.
- Samsung Electronix Co Ltd. – 266 applications.
- LG CHEM LTD – 228 applications.
- Panasonic Intellectual Property Management CO LTD – 228 applications.

Despite the reported decline in the patent application activity of these companies, their research activity continues throughout the entire research period.

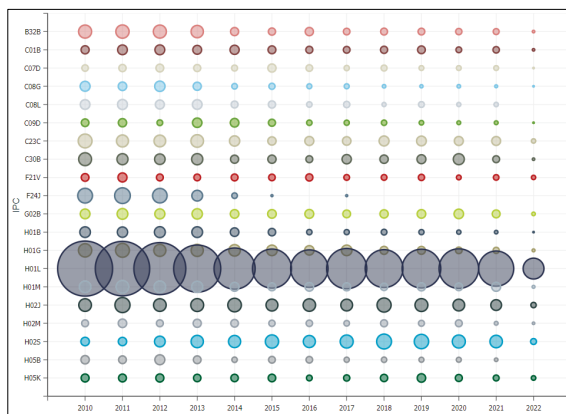
Patents granted in the period 2010-2022

The dynamics of the total number of patents granted in the period 2010-2022 repeats the observed negative downward trend in the activity of patent applicants for the same period (see Figure 7). The number of patents granted decreased on average annually by 11.76%.

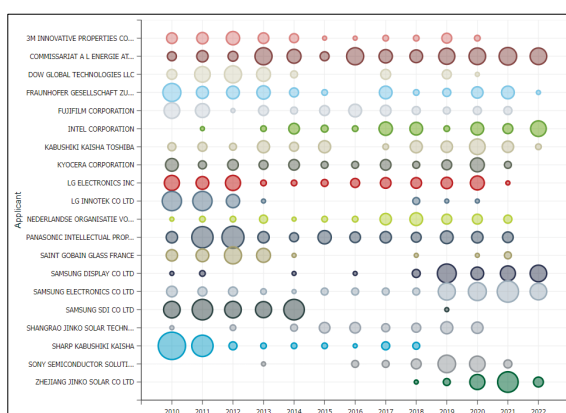


Source: PATSTAT / Authors' calculation
Fig. 7. Dynamic of total patent granted for the period 2010-2022

Analysing the granted patents by PV technology application area (Figure 8), the highest number of patents were granted in 2010, the IPC index found most frequently in them being **H01L**. Next are the indices **C23C, H02J** and **C30B**, which repeats the requesting activity in the field.



Source: PATSTAT / Authors' calculation
Fig. 8. Patent grants in the top 20 IPC classes in the field of PV technologies



Source: PATSTAT / Authors' calculation
Fig. 9. Patent holders

The patent holders (see Figure 9) where there is the greatest concentration of rights in the field of photovoltaics are:

- Commissariat A L Energie Atomique Et Aux Energies Alternatives – 162 patents granted.
- Panasonic Intellectual Property Management CO LTD – 136 patents.
- Samsung Electronix Co Ltd. – 115 patents.
- Samsung SDI CO LTD – 103 patents.
- Sharp Kabushiki Kaisha – 92 patents.
- Fraunhofer Gesellschaft zur Forderung der Angewandten Forschung EV – 92 patents.

CONCLUSION

In summary of what has been written so far, it is necessary to consider the growing importance of patent-based indicators as a source of information on the technological development of the economy and to measure

the results of scientific and technological activity.

The information on patent activity in the field of environmentally sound photovoltaic technologies is indicative of the development of renewable energy sources, the purpose of which is to displace the use of conventional energy sources. The analyzed data prove the continuing development of the sector, albeit at a slow pace against the background of the measured activity at the beginning of the studied period. Prerequisites for this can be sought both in the high efficiencies achieved for patented technologies and with the awareness of the fact that even environmentally friendly technologies leave they're not so "harmless" environmental footprint.

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