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Technological Mapping of the Photovoltaic Solar Energy Industry by Patent Documents Deposited in Brazil

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Abstract

Photovoltaic solar energy is a renewable form of electricity obtained directly from solar radiation using a semiconductor device called a photovoltaic cell. This article aims to map and identify the main characters and the evolution of the technological challenges presented by the technologies involving photovoltaic solar energy by monitoring patent documents filed between 2003 and 2011. Making it possible for the public to ensure, in practice, the way the "expertise" obtained from the technical information in documents can aggregate knowledge of a technological standpoint, applied to the photovoltaic solar energy field. So, the study methodology uses the analysis of patent applications filed in the Brazilian office extracted from PatBase[®] (Minesoft)[®]. The main areas are: (a) semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, and others; (b) assemblies consisting of a plurality of individual semiconductor or other solid state devices; and, (c) coating by vacuum evaporation, by sputtering or by ion implantation of the coating forming material. This sector is highly influenced by governmental politics such as The Brazilian Normative Resolution 482 of the National Electric Energy Agency (ANEEL) and The Green Patents Program of The Brazilian National Institute of Industrial Property (INPI).

Keywords

Solar Energy, Photovoltaic, Patent Documents, Technological Mapping.

1. Introduction

Over the past centuries society has followed the environmental degradation resulting from rapid technological and industrial growth. The inevitable exhaustion of natural resources has worried society as well as encouraged the establishment of public policies to encourage sustainable development (Melo; Czarnobay, 2012).

Photovoltaic solar energy is a renewable form of electricity obtained directly from solar radiation using a semiconductor device called a photovoltaic cell. This article aims to evaluate the technologies involved in this scenario, data of patent documents extracted from the PatBase[®] (Minesoft)[®] is used, filed from 2003, of the international patent classifications (IPC's) related to the solar photovoltaic industry. From these documents were extracted: (a) year of filing, (b) countries of filing, and (c) classifications (IPC's). Obtaining the historical evolution of the patent documents on photovoltaic solar energy from 2003 and the regions of greatest interest for protecting this technology.

1.1. Contextualization on Photovoltaic Solar Energy

Using the solar energy is a technically and economically viable project, but it is still explored incipiently in Brazil, due to intermittency and the high cost compared to other energy sources such as hydropower. Studies indicate a drop of up to six times on the price of the kilowatt generated from solar energy by the year 2015 (EIA, 2002,2011;).

The photovoltaic effect was first observed in 1839 by Edmond Becquerel who checked that the metallic plates, immersed in an electrolyte, produced a small voltage difference when exposed to light (Becquerel, 1839).

Photovoltaic solar energy is produced in photovoltaic cells that are constituted by a semiconductor material, silicon, to which doping substances are added, creating a suitable medium for establishing the photovoltaic effect, i.e. the direct conversion of solar radiation power associated with electrical power (Castro, 2008). Cells are the smallest element of the photovoltaic system, to obtain higher power it is necessary to link them in serial or parallel, forming the photovoltaic panels.

Nowadays photovoltaic systems are used in a wide range of applications in small and medium power, such as watches, calculators, rural electricity, automotive accessories and distributed energy generation.

1.2. Environmentally Sound Technologies - EST

Environmentally sound technologies are defined by UNFCCC¹ as technologies that protect the environment, are less polluting, use all resources in a more sustainable manner, recycle more of their wastes and products, and handle residual wastes in a more acceptable manner than the technologies for which they were substitutes and are compatible with nationally determined socio-economic, cultural and environmental priorities. The term includes hard and soft technologies (UNFCCC, 2006). Environmental technology (envirotech), green technology (greentech) or clean technology (cleantech) is also used to describe sustainable energy generation technologies such as photovoltaics, wind turbines, bioreactors, etc.

¹ United Nations Framework Convention on Climate Change (UNFCCC) is a periodic wide world conference opened for signature on May 9, 1992. The most current documents are accessible at the website of UNFCCC or directly at <http://unfccc.int/2860.php>

The IPC Green Inventory², was launched in 2010, it is a powerful online tool designed for searching and retrieving patent documents related to green technology from around the world in order to contribute to the accessibility of patent information about green technologies.

In Brazil, The Green Patents Program adopts the green technology adopts this inventory excluding areas: (a) administrative, regulatory or aspects of design and (b) nuclear power (Resolução INPI, 2012).

1.3. Patent documents as technological information source

Nowadays, the focus is on developing methods to extract technological "expertise" of databases, for example, newspapers and the internet. It is highlighted Intelligence Technology (IT) which aims at capturing and disseminating technological information needed for strategic planning enabling industries to identify and approach technological opportunities that can practically affect the future growth and survival of their businesses. (Buzzanga, 2008).

In this scenario, patent documents are an excellent source of technological information, as well as to disseminate technical information worldwide about new inventions, these documents are not of exclusive use, and used, for example by scientists and industrial technicians, to elaborate marketing strategies, studies on risk analysis and strategic planning as well as in research and development (R & D) "(Santos *et al*, 2011). Patent documents regarding their legal effect can be: (i) documents of patent applications, and (ii) granted patent documents (or simply - Patent). The first set of documents referred to those documents filed for the first time at a patent office, a patent application, while the second concept, imputes to a title granted by the state to inventors, authors or other individuals or entities who hold the rights over the creation of the invention, during the period of its validity (INPI, 2012).

The patent documents have as necessary conditions to patentability: a detailed technical description of the invention (clarity), novelty, inventive step and industrial application. And as to data from the World Intellectual Property Organization (WIPO), about 70% of all information is in the form of patents, and over 80% of these cases, their content will not be published in any other source of information (WIPO, 2012; APPI, 2011).

Patent documents are classified in most patent offices, according to a unique coding system: the International Patent Classification³ (IPC) a set of letters and numbers that classify patents according to their technical areas. The IPC is a tool that enables the organization of the patent documents used in order to facilitate the access to technological and legal information contained

² IPC Green Inventory is designed for searching and retrieving patent documents related to green technology from around the world in order to contribute to the accessibility of patent information about green technologies, in a number of fields including alternative energy production, energy conservation, transportation, waste management, and agriculture and forestry (WIPO, 2010).

³ The International Patent Classification (IPC) is a hierarchical system in which all technological sectors are divided into a number of sections, classes, subclasses, groups and subgroups. This system is essential for retrieving patent documents for assessing novelty and inventive step of an invention, or to determine the state of the art in a particular field of technology and it was set after the Strasbourg Agreement of 1971, which established a common classification to patents, utility models and similar securities.

therein. The most current versions of IPC can be accessed on the website of WIPO⁴ (WIPO, 2012).

As shown above, the aim of this article is to map and identify the main characters and the evolution of the technological challenges presented by the technologies involving photovoltaic solar energy by monitoring patent documents filed between 2003 and 2011. Making it possible for the public to ensure, in practice, the way the "expertise" obtained from the technical information in documents can aggregate knowledge of a technological standpoint, applied to the photovoltaic solar energy field.

2. Methodology

For the analysis of mapping the technologies involving photovoltaic solar energy sector the patent documents extracted from the PatBase[®] (Minesoft[®]) database were initially used on December 5, 2012, recovering all patent documents of photovoltaic solar energy deposited in Brazil.

In search strategy for retrieving patent documents were used: (a) IPC classification, (b) "country code" (country of filing): BR = Brazil, and (c) the period: between 2003 and 2011. The IPC's list of classifications used, i.e., related to the photovoltaic solar energy sector is the "IPC Green Inventory"⁵ the same adopted by "The Green Patent Program" of Brazil. The IPC's used were: C01B33/02, C23C14/14, C23C16/24, C30B29/06, G05F1/67, F21L4/00, F21S9/03, H02J7/35, H01G9/20, H01L25, H01L31/042, H01L27/142, H01L27/30, H01L31/00-31/078, H01L51/42-51/48, H01M14/00 and H02N6/00. From the retrieved data: number of patent documents, classification and filing year, a detailed quantitative analysis of the number of patent documents per year divided by classification of interest in each area of the photovoltaic solar energy sector was performed.

3. Results and Discussion

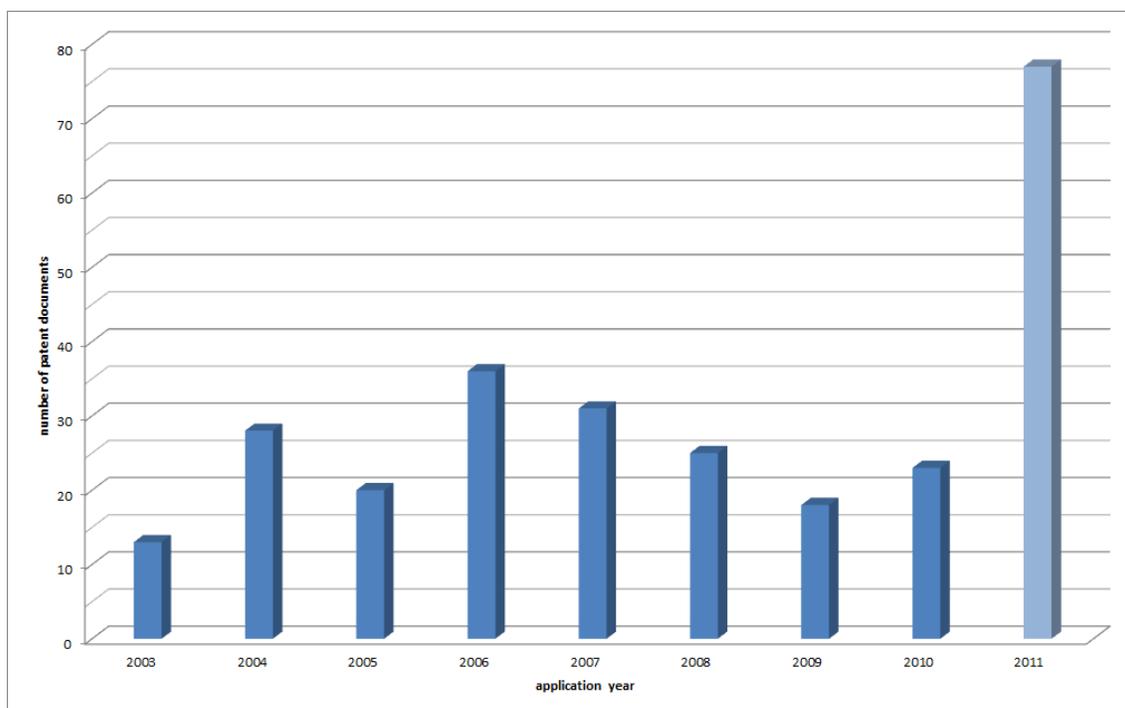
There was a total of 306 retrieved documents, from the PatBase[®] database using the follow search strategy: (a) "IPC Green Inventory" classification for photovoltaic solar energy, (b) "country code" (country of filing): BR = Brazil, and (c) the period: between 2003 and 2011.

Figure 1 represents the temporal evolution of the patent documents of photovoltaic solar energy. The value of 2011 could be uncompleted because of the confidential period of 18 months between the filing date and the publication date because the patent documents are only available for viewing after the period of confidentiality, and also due to 30 months that the PCT has to reach the national phase from the filing date, as these patent documents are only available in national databases after the publication in the national stage, but maintain the filing date of the PCT application.

⁴ The most current versions of IPC are accessible at the website of WIPO or directly at <http://ipc.inpi.gov.br/ipcpub/#refresh=page>

⁵ The "IPC Green Inventory" was developed by the IPC Committee of Experts in order to facilitate searches for patent information relating to so-called Environmentally Sound Technologies (ESTs).

<http://www.wipo.int/classifications/ipc/en/est/>



Elaborated by the authors
 Source: Base PatBase® (Minesoft)®

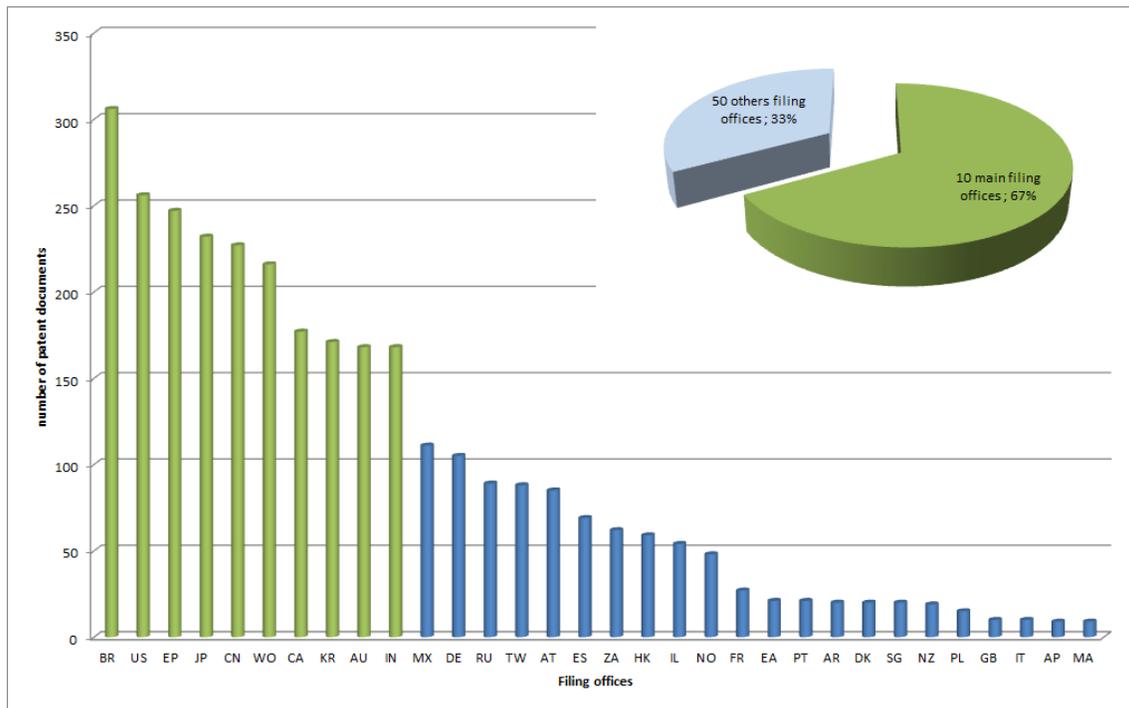
Figure 1: Temporal evolution of patent documents related to photovoltaic solar energy.

Looking for possible factors that had caused a large increase in the number of patents documents in 2004, which nearly tripled from a year earlier - indicating the development of the country for investments in R & D and technological maturation. It might be caused by the attempts to reduce the shortage of access to electricity in several regions, which have been created along with energy concessionaires and some institutions of rural electrification initiatives involving photovoltaic systems, for example, The Countryside Electricity Program (“Programa Luz do Campo”) released in 2000 (Flanagan, Cunha, 2002). But only in December 1994, the Energy Development Program for States and Municipalities (“Programa de Desenvolvimento Energético de Estados e Municípios” - PRODEEM) there was an effective incorporation of the use of photovoltaic energy in the whole country. In April 2002, under Brazilian Law No. 10,438, reviewed by Brazilian Law No. 10762, November 2003, which was established the Incentive Program for Alternative Sources of Electric Energy (“Programa de Incentivo às Fontes Alternativas de Energia Elétrica” - PROINFA). In 2004, during the International Conference for Renewable Energies, Brazil signed an agreement with Germany for cooperation in the area of alternative energy. Also in 2004, The Electricity for Everyone Program (“Programa Luz para Todos”) was launched aiming to end the exclusion of energy, raising high expectations for the use of photovoltaic solar energy, mainly in the Amazon region (Varella et al, 2007).

Another representative growing of the patent documents happened in 2011, due to the publication of Brazilian Normative Resolution 482 of the National Electric Energy Agency (ANEEL), which was only published on April 17, 2012, but had already been debated in the political arena and in academia. The resolution defines and regulates the deployment of micro

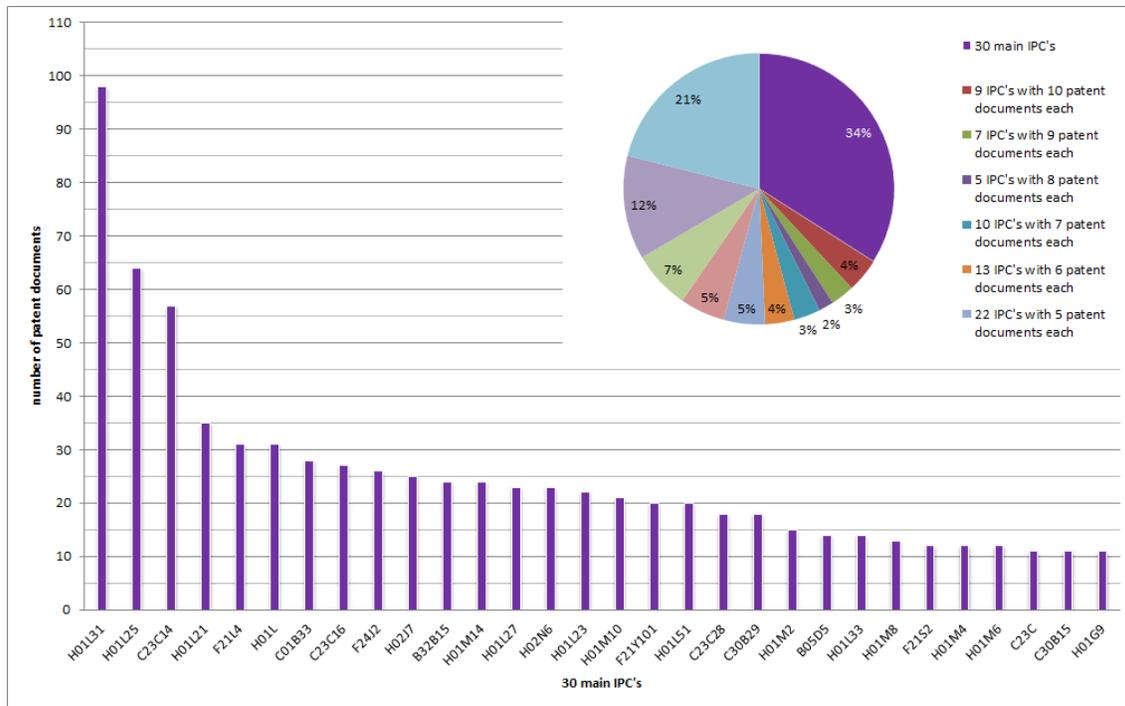
generation and mini generation systems, as well as the compensation electricity system , thus allowing the installation of photovoltaic systems connected to the electricity network (GRD), as happened in Germany after the publication of the Laws of Renewable Energy (EGG) in 2000. Also on April 17, 2012, the Brazilian National Institute of Industrial Property (INPI) implemented The Green Patents Program (“Programa Piloto de Patentes Verdes”), which accelerates the examination of applications for invention patents, concerning categories of alternative energy, transportation, energy conservation, waste management and agriculture.

The filing offices of patent documents noticed that the distribution of documents have being concentrated in 10 offices which hold 67% of patent documents. Among them the highlighted are, besides Brazil (BR) - focus of the article, the: (a) United States - U.S., (b) European Office - EP, (c) Japan - JP, (d) China - CN, (e) World Intellectual Property Organization – WO; with over 200 patent documents filed related to the sector of photovoltaic solar energy and offices: (a) Canada - CA, (b) South Korea - KR, (c) Australia - AU and, (d) India - IN with over 150 documents, in each (Figure 2). The countries covered by these offices indicate the market in which the photovoltaic solar energy sector has an interest of protection.



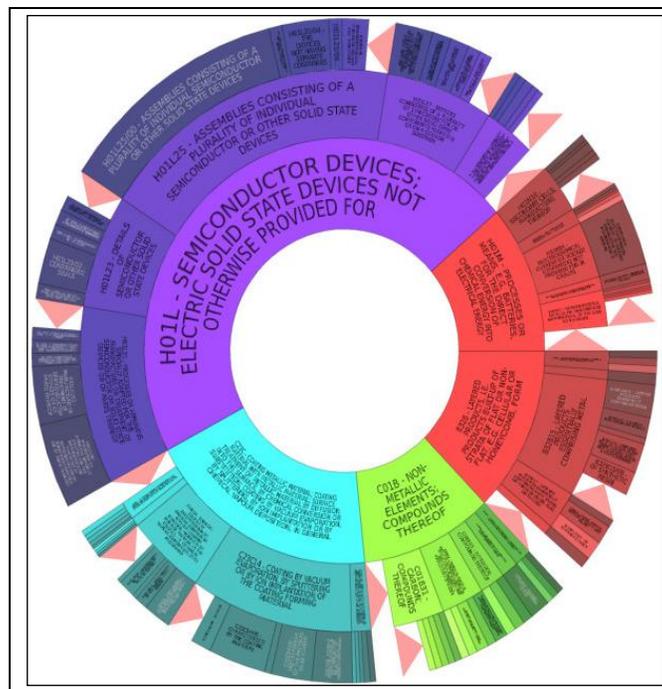
Elaborated by the authors
Source: Base PatBase® (Minesoft)®

Figure 2: Filing offices of patent documents related to photovoltaic solar energy.



Elaborated by the authors
 Source: Base PatBase® (Minesoft)®

Figure 3: IPC's of patent documents related to the photovoltaic solar energy.



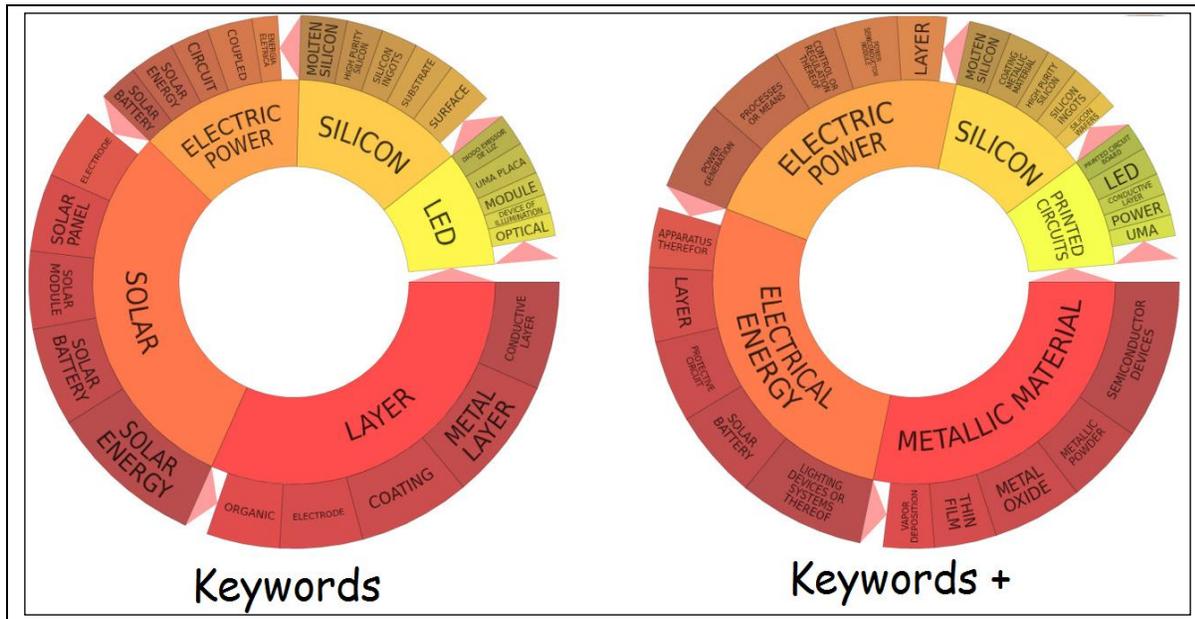
Elaborated by PatBase® (Minesoft)®
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Figure 4: IPC's of patent documents related to the photovoltaic solar energy.

Regarding the international patent classification (IPC) were all occurrences stratified whether they were the first classification of the document or other document classifications and the results are shown in Figures 3 and 4.

The main classifications with over 55 occurrences are: (a) "H01L31" - semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation; processes or apparatus specially adapted for the manufacture or treatment thereof or of parts thereof; details thereof; (b) "H01L25" - assemblies consisting of a plurality of individual semiconductor or other solid state devices, and (c) "C23C14" - coating by vacuum evaporation, by sputtering or by ion implantation of the coating forming material.

Figure 4 shows the hierarchic circular representation of the main IPC of the first 2000 records where the width of its circular cross section is proportional to the number of occurrences of IPC. In the central ring are the five major subclasses, each represented by one color, in the intermediate ring are their major groups, and in the outer ring the main subgroups. The principal is "H01L" with approximately half of the ring then "C23C". Note that in the intermediate ring the IPC "H01L25" is highlighted. The difference between the results of Figures 3 and 4 is due to the limitation of the stratification shown in Figure 4 which uses only the first 2000 records, while Figure 3 uses all records.



Elaborated by PatBase® (Minesoft)®
 Source: Base PatBase® (Minesoft)®

Figure 5: Keywords of patent documents related to photovoltaic solar energy sector.

The graphical representation of the main keywords ("Keywords") - Figure 5 - has a circular hierarchicity in which the width of the circular section is proportional to the number of occurrences of the word. The circular shape "Keywords" is the representation of the occurrence of keywords in the title and abstract of the patent documents, while "Keywords +" represents the

occurrence of keywords in the title and abstract combined with the full definition of the main IPC.

The main keywords from the title and abstract - "Keywords" are: (a) solar and (b) layer. While related to "Keywords +" are: (a) metallic material, (b) electrical energy, (c) electric power.

4. Conclusion

The development of this paper, has shown the potential of strategic information that patent documents can offer in order to support a management process and technological monitoring for technologies involving photovoltaic solar energy due to the potential of strategic information contained in these documents.

As seen, the use of photovoltaic solar energy had been showing timid growth of patent documents in Brazil until 2009, this is due to the stimuli from government programs that had not been enough until then. Brazil has a high potential for utilization of solar energy, due to strong solar radiation, especially in the Northeast. But, The Brazilian Normative Resolution 482 of the National Electric Energy Agency (ANEEL) and The Green Patents Program of The Brazilian National Institute of Industrial Property (INPI) influenced the growth of patent documents in Brazil in 2011.

And the main IPC groups are: (a) "H01L31" - semiconductor devices sensitive to infra-red radiation, light, electromagnetic radiation of shorter wavelength, or corpuscular radiation and specially adapted either for the conversion of the energy of such radiation into electrical energy or for the control of electrical energy by such radiation; processes or apparatus specially adapted for the manufacture or treatment thereof or of parts thereof; details thereof; (b) "H01L25" - assemblies consisting of a plurality of individual semiconductor or other solid state devices, and (c) "C23C14" - coating by vacuum evaporation, by sputtering or by ion implantation of the coating forming material.

Concerning keywords one can conclude that the main focus of the technologies studied in the photovoltaic solar energy sector are related to solar and metallic materials.

In relation to the interest of technologies protection, which is in the countries covered by the offices of industrial / intellectual property in which the patent documents are deposited, for technologies involving photovoltaic solar energy one can include: Brazil - focus of the article, the U.S., European Office, Japan, China, and the World Intellectual Property Organization. It is concluded that technologies that involve solar photovoltaic energy in Brazil are also protected in other countries.

From the above it can be concluded that the focus of the technologies in the photovoltaic solar energy sector lies in the semiconductor devices including assemblies consisting of a plurality of individual semiconductor, and, coating forming material. And besides Brazil, these patent documents are deposited; mainly in the United States Office, European Office, Japan Office, China Office and the World Intellectual Property Organization; indicating also protection interest in the countries covered by these offices.

5. Perspectives

The perspectives of the development of technologies related to the photovoltaic solar energy indicate that it should be in a technological peak, i.e., at the height of an advance development of semiconductor devices among other technological advances.

The publication of The Brazilian Normative Resolution 482 of the National Electric Energy Agency (ANEEL) opens a new range of possibilities for both production technology and for the socio-economic sector. It is perceptible nationwide an increase of companies offering products or services related to photovoltaic solar energy, increasing the need for skilled labor.

Over the past decade, multinational companies set up in Brazil in order to use the large energy potential of solar radiation incident in Brazil. The speed of the patents recognition process promised by The Green Patents Program of The Brazilian National Institute of Industrial Property (INPI) encourages the patents documents about sustainable development and consequently the creation of new national technologies. It has been observed that until today much of the technology employed in the use of photovoltaic energy is imported from China and Germany.

It is expected that the Brazilian Federal Government implements new politics to encourage the use of renewable energy, especially regarding photovoltaic energy, stimulating the energy sector. Since the publicly traded companies in the energy sector experienced a decline in the stock market after the announcement of tariff reduction made by the Brazilian Government. The index of Electricity (IEE) of Bovespa (Bolsa de Valores de São Paulo) recorded by October this year, down more than 12%, due to tariff reduction and the period of renewal of concessions, a similar rate was recorded in 2008, when the economic crisis occurred (MME, 2012; BNDES, 2005; Goldemberg, 2004).

Leading companies in the energy sector must adapt to the new national scene, where anyone can become a generator of energy, not just consumers. As well as diversify its energy matrix, which is already visible in the latest newsletter of the Brazilian Ministry of Mines and Energy.

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